PHONOLOGICAL ENCODING IN LANGUAGE PRODUCTION

A PRIMING STUDY

ANTJE SUSANNE MEYER

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1 Introduction

Theories of language production often broadly distinguish three types of processes involved in the generation of an utterance: its conceptualization, its formulation, and its articulation (Kempen, 1977; Kempen & Hoenkamp, 1987).

The processes of the first type are concerned with the planning of the content of the utterance. The speaker must focus on a certain idea she wants to talk about and must decide which aspects of that idea to verbalize and in which order, keeping in mind relevant characteristics of the listener and of the communicative situation (Herrmann, 1982, 1985; Hörmann, 1981; Levelt, 1981).[1] The output of these processes is usually taken to be a propositional structure describing the content of the utterance. It is handed over to the next group of processes to be formulated (Herrmann, 1982; Schlesinger, 1977). Following Levelt and Schriefers (1987), I will call this representation the preverbal message.

The formulation of an utterance can be divided into three main components: the selection of the lexical items (Kempen & Huijbers, 1983; Levelt & Schriefers, 1987), the formation of the syntactic structure (Bock, 1982; Kempen & Hoenkamp, 1987), and the generation of the sound form of the utterance.

The output of the formulation processes is a phonetic description of the utterance. It can be viewed as a set of commands specifying certain combinations of articulatory gestures. The interpretation and execution of these commands by the articulatory processes leads to overt speech (Browman & Goldstein, 1986; Fowler et al., 1980; Kent & Minifie, 1977).

The present research is concerned with one of the components of the formulation of the utterance, namely the generation of its sound form. Before saying more about this, I will briefly discuss the relationships between the three components of the formulation process.

In many models of language production, most notably in Garrett's (1975, 1980, 1982) theory, the lexical selection and the syntactic encoding of an utterance are viewed as two processes which are both governed by the preverbal message, but which do not directly affect each other. The lexical items are selected, simultaneously the syntactic frame is generated, and then the selected items are associated to the positions of the frame. More precisely, the formulator in Garrett's model generates *two* representations of the utterance in successive processing stages. During the first stage, the functional representation is created which includes semantically specified lexical items assigned to syntactic roles (such as main verb, subject, direct object, and so on). The word order is not yet determined. In the second stage, the positional representation is generated. This is a phrase structure representation of the sentence, specifying, among other things, the order of the words (Bock, 1987a).

In other models (Kempen & Hoenkamp, 1987; Stemberger, 1985a), lexical selection and syntactic frame building are viewed as interactive processes. Kempen and Hoenkamp, for instance, have suggested a "lexically driven" model, in which the formulator inspects the preverbal message and selects lexical items to express it. Each lexical item is syntactically specified and can be assigned to a position in the developing syntactic representation. In addition, many lexical items in their turn call upon syntactic procedures which extend the syntactic structure, creating new positions to which additional lexical items are associated.

Irrespective of how the relationship of lexical selection and syntactic encoding is conceptualized, models of language production generally agree that neither component interacts heavily with the generation of the sound form of the utterance. In Garrett's model, for example, the lexical items are selected exclusively on the basis of their meaning, their sound form being irrelevant. The functional representation only describes the meaning and the syntactic structure of the utterance, not its form. In the next processing stage, a syntactic frame is generated, whose slots specify the serial order of the lexical items; at the same time, their word forms are retrieved, and then the phonologically specified lexical items are associated to the positions of the frame. Similarly, Kempen and Hoenkamp (1987) assume that the preparation of an utterance involves two discrete stages. The first is the lexico-syntactic stage in which lexical items are selected on the basis of their semantic and syntactic specifications and the sentence structure is built up; the second is the morpho-phonological stage which creates the phonological structure of the utterance. Kempen and Hoenkamp refer to the specification of a word in terms of its semantic and syntactic features, which is accessed in the first stage, as lemma, and to its form specification, which is accessed in the second stage, as lexeme.

Evidence supporting the assumption that the formulator uses the lemma and the lexeme of a word in successive processing steps is provided by Garrett's (1975, 1980) comparison of two classes of speech errors, namely of word and sound exchanges. These errors do not only differ in the type of error units (words vs. sounds), but also in the constraints they observe. Exchanged words typically belong to the same syntactic category and come from different phrases (examples (1-1) and (1-2)).[2] Most sound exchanges, on the other hand, involve words of differing syntactic categories appearing in the same phrase (examples (1-3) and (1-4)). Moreover, sound errors are constrained by phonological factors. For instance, the exchanged sounds tend to be phonologically similar, sharing more phonological features than would be expected on the basis of a chance estimate, and they typically stem from corresponding syllable positions. Word exchanges are less strongly affected by phonological factors (but see below).

(1-1) dinner is being served at wine (wine is being served at dinner)
(1-2) the subject of problem raising (the problem of subject raising)
(1-3) heft lemisphere (left hemisphere)
(1-4) a pope smiker (a pipe smoker)
(Fromkin, 1973, Appendix)

These differences between word and sound exchanges suggest that they occur at different moments in the development of the utterance. Word exchanges arise at a level of representation where the formulator inspects the syntactic specifications of the lexical items and assigns them to grammatical roles, disregarding their phonological form and their surface order. Sound exchanges, on the other hand, occur later, when the sound form and the surface order of the lexical items are determined (Fay & Cutler, 1977; Fromkin, 1971).

Thus, lemmata and lexemes are apparently *used* at different moments in the formulation process. Garrett's proposal, however, includes an additional claim, namely that they are *retrieved* at different times. At the functional level, words are assumed to be represented only in terms of their semantic and their syntactic characteristics, but not in terms of their form. Conversely, at the positional level, they are exclusively represented in terms of their form, but not in terms of their meaning and syntactic features. This implies, first, that the lemma and the lexeme of a word are accessed strictly sequentially, with the access of the lexeme beginning only after the lemma has been selected, and second, that the processing at the functional level is independent of the processing at the positional level. The selection and ordering of the lemmata should, for instance, not be affected by phonological factors.

As Dell and Reich (1981) have pointed out, this claim is unlikely to be correct. Analysing a corpus of speech errors, they present evidence showing that errors which supposedly arise at the functional level are affected by phonological factors, and conversely, that errors which are taken to occur at the positional level are influenced by semantic factors. For instance, the words involved in word exchanges tend to be phonologically more similar than expected on the basis of a chance estimate (Harley, 1984; Stemberger, 1985b).

Dell and Reich interpret these findings within a spreading activation model of language production. The mental lexicon is viewed as a network of connected nodes representing linguistic units, such as words, phonological segments (vowels and consonants) and phonological features.[3] Each node is linked to the nodes representing its subordinate units; for instance, a word connects to its phonological segments, which in turn connect to their features. An activated unit sends a certain proportion of its activation to all nodes which are linked to it. Thus, an activated word transmits some of its activation to its phonological segments, which send some activation upwards to all words they are part of. When the functional representation is generated, the activation levels of the word nodes are inspected. In filling a given slot of the syntactic frame, only those items are considered which meet the syntactic specifications of that slot, and the most highly activated of these units is selected. The phonological specifications of the words are only considered later, when the positional representation of the utterance is created. When a sentence includes two phonologically related words of the same category, the word nodes activate each other via their shared phonological segments, so that their activation levels become more highly correlated than the activation levels of two phonologically unrelated words and the likelihood of their being selected in the wrong order and associated to inappropriate slots of the functional representation is increased. In other words, the tendency of exchanged words to be phonologically similar is due to feedback from the segment level to the word level.

Bock (1986, 1987b) has run a series experiments, investigating the effects of semantic and phonological factors on the sentence structure (see also Levelt & Maassen (1981) for a related study). She asked her subjects to describe pictures of events using simple sentences, such as "the lightning hit the house" or "the man was stung by the bee". In the first two experiments (Bock 1986), each drawing was preceded by a prime which was either semantically or phonologically related to one of the nouns that were expected in the description. It turned out that the sentence structure chosen by the subjects was affected by the semantic primes, with the primed noun tending to appear before the unprimed one, but not by the phonological primes.

In the second study (Bock, 1987b), only phonological primes were used, which were, furthermore, more closely related to their targets than the phonological primes in the earlier experiments. Now a small, but significant phonological priming effect was obtained, with the primed word tending to follow the unprimed one. Apparently, the prime inhibited the target (which as such is an interesting finding), and its mention was postponed as long as possible. Following Levelt and Maassen (1981), Bock argues that this result does not challenge the assumption of a level of representation where lemmata are assigned to syntactic roles without any consideration of the accessibility of the word forms. Only at the next level of processing, when the word forms are to be retrieved, the primed word form is found to be inhibited. If that word was originally meant to be mentioned early in the sentence, the syntactic structure of the utterance is revised so that the inhibited lexeme appears later. Thus, the inhibition of the primed word form does not directly affect the syntactic frame building, but leads to a change of the frame if the primed word form cannot be selected in time. This account is supported by the distribution of the speech dysfluencies in the subjects' utterances. Dysfluencies were observed more frequently at the beginning of those utterances where, according to this account, a revision of the syntactic structure should take place than at the beginning of the remaining utterances, where no change of the syntactic structure was required.

Thus, both the speech error evidence and the experimental results just described show that the generation of the functional representation of an utterance can be affected by the relative accessibility of the word forms. But this does not violate the claim that the lemma and the lexeme of a word are independent representational units which are selected at different points in time and are assigned to positions in different representations of the utterance (Bock, 1987a; Levelt & Schriefers, 1987). The current research investigates the question of *how* the sound form of a word is created, given the specification of its meaning.

In linguistic theory, a distinction is made between a fairly abstract *phonological* representation of a word form and a more detailed *phonetic* representation, which is the input to the articulatory system (see, for example, Browman & Goldstein, 1986; Chomsky & Halle, 1968; Crompton, 1982; Mohanan, 1986). Sometimes, intermediate representations are postulated, like Mohanan's (1986) syntactico-phonological representation, which captures the effects of phonological rules applying across words.

Speech error evidence is available to suggest that in language production both a phonological and a phonetic representation of an utterance are generated and that most errors arise during the generation of the former representation. This can be inferred from the fact that misplaced sounds are usually accomodated to their new environment or that the environment is accomodated to the intruding sound, following the rules of the language in question (Berg, 1987; Fromkin, 1971, 1973; Garrett, 1975, 1982; Stemberger, 1985c).

For instance, a stop consonant which moves from a word-initial to a word-internal position, like the segment [p] in example (1-5), is not aspirated any longer in its new location. Conversely, a stop which appears word-initially instead of word-internally, like the [t] in the same example, receives aspiration in the new context, as required by the rules of English phonology (Fromkin, 1973). Errors in which the environment accomodates to a misplaced segment are given in examples (1-6) to (1-10). In examples (1-6) and (1-7), the plural morpheme is accomodated to the new consonant to its left. Therefore, the error must have taken place before the form of the plural morpheme was determined. Similarly, examples (1-8) and (1-9) show that the errors must have taken place before the morphophonemic rule applied that governs the form of the determiner. To give a final example, consider the fact that English vowels are longer when the following consonant is voiced than when it is unvoiced. In a tongue-twister experiment, Shattuck-Hufnagel (1985a) found that exchanges of syllable-final consonants (example (1-10)) were accompanied by the appropriate adjustment in the length of the preceding vowels.[4]

(1-5) speak and tomatoes (steak and potatoes)
(Fromkin, 1973, Appendix)
(1-6) plan the seats [sijts] (plant the seeds [sijdz])
(1-7) tap [stabz] (tab stops)
(1-8) a meeting arathon (an eating marathon)
(1-9) an istory of a hideology (a history of an ideology)
(Fromkin, 1971, p. 41)
(1-10) dick dug (dig duck)
(Shattuck-Hufnagel, 1985a, p. S85)

Thus, the creation of the sound form of a word can be broken down into two components, the generation of its phonological representation and the development of its phonetic representation. It is the former step, the phonological encoding of a word, which is at issue here.

A theory about the processes creating a certain type of representation has to make fairly specific assumptions about the result of these processes, that is, about the structure of the representation in question. As a working hypothesis, I assume that the phonological representations which are generated in language production are structured as proposed in nonlinear phonology. I will provide an outline of that framework in chapter 2.

Much of the psycholinguistic evidence concerning phonological encoding is provided by various speech error phenomena, some of which will be discussed in chapter 3. One conclusion from the speech error analyses should, however, be mentioned right away: Fromkin (1971, 1973) has argued that any linguistic unit which regularly functions as error unit in slips of the tongue must be a planning unit of language production. Thus, the fact that there are errors in which one or more incorrect sounds are selected or in which the intended sounds are uttered in a wrong order indicates that the phonological representation of a word is generated by selecting and combining sounds or groups of sounds rather than being retrieved as a whole. The occurrence of so-called tip-of-the-tongue states, in which the speaker has a clear idea of the concept she wants to mention and a feeling of knowing the respective word, but can only retrieve parts of its form (such as the first one or two phonological segments, the number of syllables, or the stress pattern), points in the same direction (Browman, 1978; Brown & McNeill, 1966; Hörmann, 1977).

This view of phonological encoding as a constructive process raises two sets of questions: first, what are the sublexical units which are retrieved and combined in the phonological encoding of an utterance? Are they, for instance, phonological features, segments, or syllables? Much attention has been paid to this issue in the analyses of speech errors, and the relevant evidence will be summarized in chapter 3.

The second set of questions concerns the process of phonological encoding. The specific issue which is investigated here is the time course of this process. Sound errors indicate that word forms are assembled out of smaller units, but they reveal nothing about the temporal aspects of this process. One possibility is that the sublexical units of a word are selected in parallel and are subsequently ordered. Alternatively, they could be retrieved sequentially; a plausible guess is that the beginning of a word is created before its end.

Dell (1986) has proposed a model of phonological encoding which is tailored to explain certain speech error phenomena, but which is intended as a general model of language production. This model is summarized in chapter 4. It makes certain predictions about the temporal order in which different parts of a phonological representation are generated. These predictions are not only interesting in their own right, but also because they relate directly to Dell's assumptions about the structure of phonological representations. They were tested in three series of experiments, reported in chapters 6 to 8. The first series investigated the temporal order in which successive syllables of a word are encoded, the second and third series examined the phonological encoding of the segments within a syllable. Chapter 5 provides a description of the paradigm employed in these experiments.

The experimental results suggest certain modifications of Dell's model, which are summarized in chapter 9. Finally, it is discussed how the modified model accounts for the speech error phenomena introduced earlier.

Notes

1. For stylistic reasons, I will use "she", "her", and "herself" as generic pronouns instead of "he or she", "him or her", and "himself or herself".

2. In all examples of speech errors the incorrect utterance is listed first, followed by the intended utterance.

3. Dell and Reich (1981), as well as many other authors referred to in the present text, use the term "phoneme" which is usually broadly defined as a set of features specifying a sound of a given language. But this term implies a number of assumptions which are not generally accepted in current linguistic theory, such as the claim that all features have the same scope and that there exists no particular order among the features defining a sound. Therefore, I will use the more neutral term "(phonological) segment" throughout this text (see chapter 2).

4. It is, of course, not claimed here that *all* sound errors arise during the derivation of the phonological representation. For instance, Garrett (1975) has suggested that most sound deletions might occur in the generation of the phonetic representation. Furthermore, errors can also arise during the execution of the articulatory commands.

2 The representation of word forms in nonlinear phonology

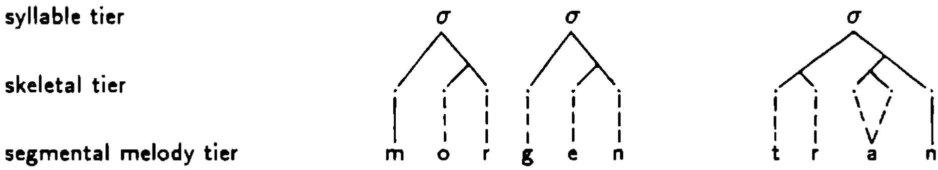
2.1 Overview

In early generative phonology, most notably in Chomsky and Halle's "The Sound Pattern of English" (SPE; 1968), a phonological representation was viewed as a linear sequence of phonological segments (vowels and consonants). The segments were defined as unordered sets of phonological features, each of which had a binary value. The only hierarchical structure imposed on the string of segments was morphosyntactic; that is, substrings of segments combined to form morphemes, words, phrases, and sentences.

Currently far more complex, multi-level phonological representations are assumed, consisting not just of one sequence of units, but of several sequences, so-called tiers.[1] Hence, the representations are termed multilinear or nonlinear. There are two major differences between the early linear framework and the recent developments. First, purely phonological hierarchical structures are assume in addition to the morphosyntactic structure, and second, the view of phonological segments as unordered sets of features is given up. I will discuss each of these differences in turn.

Recent phonological research has shown that certain phonological processes can best be described by reference to prosodic units (Kahn, 1976; Nespor & Vogel, 1986). Therefore, a hierarchical structure of prosodic levels has been introduced, including the levels of phonological phrases, phonological words, feet, and syllables. A syllable has an internal hierarchical organization: It can be divided into an onset and a rhyme, which in turn consists of a nucleus and a coda (see section 2.3). Each of these syllable constituents comprises one or more terminal positions, often called "slots", to which phonological segments are associated. The terminal positions of the syllable structure can be viewed as the units of a separate tier, the so-called skeletal tier, representing the interface between syllables and phonological segments (examples (2-1) and (2-2)).[2]

(2-1) (2-2)



(morning) (tear)

In SPE phonological segments were defined as bundles of distinctive features. This definition implies that all features have the same scope, namely one segment. Thus, the features are perfectly aligned with each other. However, a number of phenomena have been observed showing that features may differ in scope. For instance, in many tone languages a short vowel, which is analysed as one segment, takes two tones when a neighbouring vowel is deleted. Tones may also have wide scope, that is, span more than one segment. In both cases, the tone is misaligned relative to the remaining features defining the sounds (Goldsmith, 1976; Van der Hulst & Smith, 1982; Leben, 1971).

In order to represent such misalignment of features, nonlinear phonology attributes them to separate tiers and regards them as segments in their own right, so-called autosegments, which are independently associated to the slots of the skeletal tier. Since the feature-to-slot relationship is not necessarily a one-to-one association, but can also be many-to-one or one-to-many, variations in feature scope can be expressed. A feature with wide scope is associated to more than one slot, while a feature with narrow scope is only associated to one slot.

If each phonological feature is represented on a separate tier, and if features vary in scope, it can be argued that there are no such units as the traditional phonological segments which are defined as feature bundles. However, misalignment between features represents the exception rather than the rule. In Dutch and English, for example, there are long vowels, whose features are associated to two slots of the skeletal tier, and short vowels, whose features are linked to one slot. But in both cases, the scope is identical for all phonological features defining the respective sounds. This correspondence of feature scope allows one to argue for a cumulative tier, called the (segmental) melody tier by Selkirk (1984), whose units are phonological segments, defined as feature matrixes (see also Hayes, 1986). Throughout this text the term (phonological) segment will be exclusively used to refer to these units.

2.2 The linear structure of the syllable

Since the notion of the syllable will play an important role in the following chapters, it will be discussed in some detail in this and the next section. In characterizing the well-formed syllables of a given language, two issues can be distinguished: first, which sequences of phonological segments represent well-formed syllables? This question, concerning the *linear* structure of the syllable, is taken up in the present section. Second, can the segments of a syllable be grouped into subsyllabic units, and if so how? This question, concerning the *hierarchical* structure of the syllable, will be discussed in the next section.

Within the framework of nonlinear phonology, a syllable can be viewed as a template which embraces a certain number of positions of the skeletal tier and defines which class of segments can be associated to each of them and which combinations of segments are permissible. For example, the maximal syllable template of Dutch is built onto five positions of the skeletal tier, the first two of which can only be filled by consonants, the third one only by a vowel, and so on.[3]

All versions of nonlinear phonology agree that the syllable structure somehow provides the information necessary for the proper associations between the phonological segments and the positions of the skeletal tier. According to one proposal (Clements & Keyser, 1983; Halle & Vergnaud, 1980; McCarthy, 1979), the terminal positions of the syllable tree are labelled "C" or "V". These abbreviations designate the features [-syllabic] and [+syllabic] or other features or feature combinations defining consonants and vowels. Only consonants can be linked to C-positions and only vowels to V-positions.

According to a related suggestion (Levin, 1985), the slots of the skeletal tier are completely unspecified. Slots to which vowels and consonants can be associated are distinguished by their positions within the syllable. Vowels, for instance, can only be linked to those slots which belong to the nucleus of the syllable.

A third proposal has been advanced by Selkirk (1984). She argues that the major class features ([±syllabic], [±consonantal], [±sonorant]) should be eliminated from a theory of syllable structure. Instead, the sounds of a language can be arranged on a continuum of sonority, and the major classes of segments (such as vowels, glides, and obstruents) can be defined as classes of segments with identical or similar sonority values.[4] Vowels are the most sonorous, followed in decreasing order of sonority by glides, liquids, nasals, and obstruents (Hooper, 1976; Vogel, 1977).

It turns out that syllables generally conform to the so-called Sonority Sequencing Generalization (SSG):

> In any syllable, there is a segment constituting a sonority peak that is preceded and/or followed by a sequence of segments with progressively decreasing sonority values. (Selkirk, 1984, p. 116)

In other words, the segments are ordered such that their sonority increases from the margins to the center of the syllable. Based on this observation, Selkirk has proposed to specify the terminal positions of the syllable in terms of sonority indices. Following this suggestion, Van der Hulst (1984, p. 97) assumes the provisional sonority scale for Dutch given below (2-3) and demonstrates that the linear structure of Dutch syllables can indeed to a large extent be captured by reference to the sonority values of the phonological segments that can be associated to their terminal positions.

(2-3)

Sonority hierarchy of Dutch

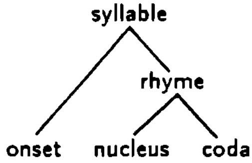
obstruents	m	n	l	r	glides	vowels
1	2	2.25	2.5	2.75	3	4

The first two positions of the syllable template can only be taken by segments whose sonority value is less than 4, that is, by consonants. The next position, the position of the peak, can only be filled by segments whose sonority value is equal to 4, that is, by vowels. Many of the constraints on combinations of segments in adjacent positions (called collocational restrictions by Fudge (1969)) can also be expressed in terms of the sonority of the respective segments. Certain sound combinations are ruled out directly by SSG. If, for example, the first position of the template is taken by [l], neither [n] nor [m] can follow it, since nasals are less sonorous than liquids. But the cluster [lr], which does not violate SSG, is not permitted in Dutch either. It can be ruled out, together with a whole class of other illegal sequences, by prohibiting clusters of segments whose sonority values are too similar (Harris, 1983; Selkirk, 1984; Steriade, 1982). The constraint that a syllable-initial obstruent may be followed by a liquid but not by a nasal can be expressed by stating that the minimal sonority difference between the segments in these positions is 1.5 on the above scale. Van der Hulst (1984) shows that nothing needs to be said about the segments associated to the last two positions of the syllable, other than that SSG may not be violated and that the minimal sonority difference between them is 0.5 on the above scale.

2.3 The hierarchical structure of the syllable

As was mentioned above, a syllable can be divided into an onset, which comprises the prevocalic positions, and a rhyme, which includes the remaining positions (see (2-4)).

(2-4)

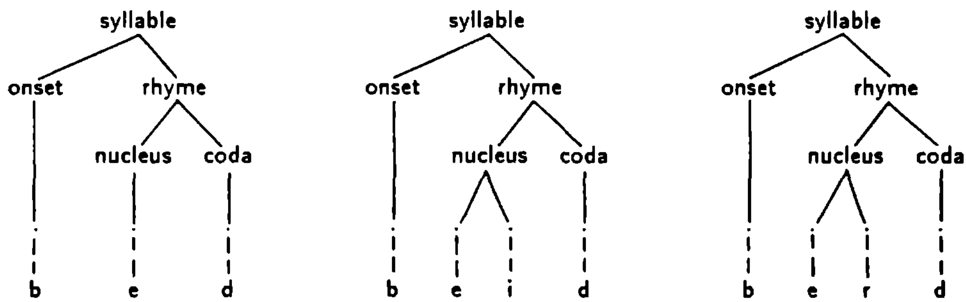


One argument supporting this distinction is provided by the involvement of the syllable positions in collocational constraints. Selkirk (1982) has argued that the immediate constituent structure of the syllable is mirrored in the distribution of constraints between the positions of the syllable. The more closely related two positions are structurally, the greater is the likelihood of their being subject to mutual collocational constraints (see also Pike, 1967). In many languages, including Dutch and English, there are sequential constraints within the onset positions and within the rhyme positions, but there are virtually no constraints which mention one onset and one rhyme position (Fudge, 1969). Hence, the constituents onset and rhyme are supported by the distribution of the collocational constraints.

A second argument for the distinction between the onset and the rhyme of a syllable is based on the relationship between syllable structure and stress assigment. In many languages, the main stress can only fall on syllables which include a certain number and/or certain types of segments. These are "heavy" syllables, as opposed to "light" syllables which do not attract stress. It turns out that the weight of a syllable is exclusively determined by the structure of its rhyme, the structure of its onset being irrelevant (Hayes, 1981; Hyman, 1985; Newman, 1972). In Dutch, for instance, syllables with a schwa are light and never stressed, whereas syllables with other types of rhymes are heavy or superheavy and may be stressed. In all cases, the weight of the syllable is independent of the structure of its onset.

Less clearcut than the distinction between onset and rhyme is the internal structure of the rhyme. Selkirk (1984) does not assume any intermediate constituents between the rhyme and the terminal positions of the syllable. In other analyses, the positions of the nucleus are separated from those of the coda (see (2-4)). The nucleus is generally considered to consist of the syllable peak plus a following glide; the coda includes the remaining postvocalic consonants (examples (2-5) and (2-6)). In some analyses (MacKay, 1970, 1972; Shattuck-Hufnagel, 1983; Stemberger, 1983; Treiman, 1984), postvocalic liquids are considered part of the nucleus rather than the coda (example (2-7)).

(2-5) (2-6) (2-7)



(bed) (bade) (Baird)

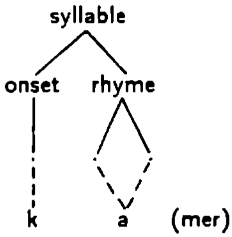
(see Stemberger, 1983, p. 141)

On the basis of the distribution of the phonotactic constraints in Dutch, it can either be argued that the immediate constituents of the Dutch rhyme are the terminal positions of the syllable structure, or that the position of the syllable peak should be separated from the following two positions.

Finally, one can distinguish between obligatory and optional syllable constituents. In both English and Dutch, the pre- and postvocalic consonants are optional; that is, a syllable may begin and end in a vowel. But in Dutch, there is an important constraint: a syllable-final vowel is practically always either a long vowel (example (2-8)) or a schwa (example (2-9)). A short full vowel, on the other hand, is usually followed by a consonant (example (2-10)). Thus, according to Van der Hulst

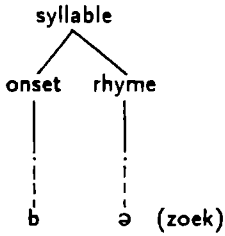
(1984), the rhyme of a syllable with a full vowel includes two obligatory positions, which can either be taken by one long vowel or by a short vowel plus a consonant. The rhyme of a syllable with a schwa, on the other hand, includes only one obligatory position, which is taken by the schwa itself. Word-final syllables have an additional optional rhyme position, which can be taken by a consonant (examples (2-11) to (2-13)).[5]

(2-8)



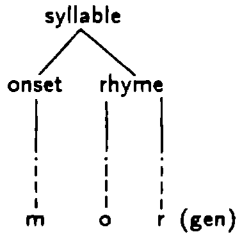
(room)

(2-9)



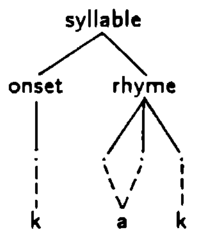
(visit)

(2-10)



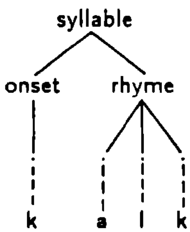
(morning)

(2-11)



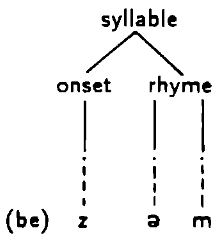
(jaw)

(2-12)



(chalk)

(2-13)



(broom)

2.4 Implications

The current research investigates the process of phonological encoding in language production. This chapter is intended to provide an outline of what the result of this process might look like. The assumption of a nonlinear phonological structure can have several implications for a model of phonological encoding.

First, if the phonological representation includes a description of the segmental melody of the word and a description of its syllabic structure, a model of phonological encoding must specify how each of these descriptions is generated.

Second, the syllabic structure and the segmental melody of the word are represented as independent tiers. Syllables are templates to which many different strings of segments can be associated. This raises the question of whether the independence of these representations should be captured in a model of phonological encoding, and if so, how this should be done. One could, for example, posit that the units of the two tiers are stored and retrieved independently and are subsequently combined to constitute a complete representation of the word form.

Finally, if the syllabic structure and the segmental melody are generated independently, a model of phonological encoding must state how the two representations are eventually combined. The positions of the syllable template are specified with respect to the types of segments which can be associated to each of them. One might wonder whether these specifications play a role in the integration of the representations.

Notes

1. See, for instance, Clements & Keyser, 1983; Goldsmith, 1976; Halle & Vergnaud, 1980; Van der Hulst, 1984; Van der Hulst & Smith, 1982; Leben, 1971; Liberman, 1975; Liberman & Prince, 1977; McCarty, 1979.

2. Most of the speech error evidence which will be discussed later comes from analyses of English corpora. The priming experiments reported below were carried out in the Netherlands with native spakers of Dutch. This is why I refer to both English

and Dutch phonology in this chapter. In the description of the Dutch syllable structure I follow Van der Hulst (1984).

3. In addition, word-initial and word-final syllables may take affixes. For example, Van der Hulst (1984) analyses word-initial [s] followed by another consonant (as in "sloom" (dull)) as a prefix and the superlative morpheme [st] (as in "promptst" (fastest)) as a suffix.

4. Phonetically, the sonority of a sound corresponds in part to its loudness (Ladefoged, 1982).

5. Van der Hulst's argument presupposes that Dutch syllables do not end in a short vowel. But it has been argued that at least word-internally such open syllable with a short vowel do occur (Booij, 1984; Trommelen, 1984). Relevant examples are words such as "koffie" (coffee), or "bakker" (baker) whose first vowel is short. These words are syllabified according to the (universal) "onset maximation rule", such that the syllable onsets are maximalized (Van der Hulst, 1984, p. 69). Since [f] and [k] are possible syllable onsets, they must be associated to the second syllable. The preceding syllable must then either end in a short vowel, or the word-medial consonant must be ambisyllabic, that is, it must be analysed as part of both syllables. Van der Hulst takes the latter position. His analysis is supported by the fact that there are no Dutch words in which one syllable could be argued to *end* in a short vowel and the next syllable *begins* in a vowel. There is always a word-internal consonant to close the syllable with the short vowel. An ambisyllabic consonant can be represented as one phonological segment which is associated to two slots of the skeletal tier belonging to successive syllables.

3 Planning units in word production: evidence from sound errors

In this chapter, I will present evidence from analyses of sound error concerning both the structure of the phonological representation and the way it is generated. After defining and broadly classifying sound errors, I will discuss how the incorrect sounds and sound sequences appearing in speech errors can best be described. This is an important issue because the error units are usually regarded as planning units of phonological encoding. I will then turn to the so-called positional constraint on sound errors, that is, to the observation that misplaced sounds are not free to take any new positions in the utterance, but that their "landing sites" are confined to positions which are similar to their target positions. The positional constraint is widely referred to in drawing inferences about the generation of the syllabic structure of an utterance.

3.1 Definition and classification of sound errors

Boomer and Laver (1968) define a speech error, or synonymously, a slip of the tongue, as "... an involuntary deviation in performance from the speaker's current phonological, grammatical or lexical intention" (p. 4). One should add that speech errors are normally taken to be non-habitual deviations from the intended utterance and that errors based on any kind of pathology are left out of consideration.

I will only discuss sound errors here. These are errors in which the utterance deviates from the intention in one or more phonological segments not corresponding to a complete morpheme. The unintended part of the utterance is called the error unit. The word in which it appears is the target word, and its syllables, segments, and features are the target syllables, segments, and features.

Following Shattuck-Hufnagel (1979, p. 299), I will distinguish five types of sound errors, namely additions, omissions, substitutions, exchanges, and shifts. Examples for each error type are given in (3-1) to (3-10). Provided that the error unit in all cases consists of a single segment, these classes of errors can be defined as follows: in an *addition*, a segment is added to a word; in an *omission*, a target segment is left out; in a *substitution*, a target segment is replaced by an incorrect segment; in an *exchange*, two segments exchange places in the utterance; and, finally, in a *shift*, a segment disappears from its appropriate location and attaches itself to another word.

Additions

(3-1) nlon-linguistic (non-linguistic)

(3-2) they bring abrout - about a ...

Omissions

(3-3) the dug – the drugs

(3-4) If this is too mentalitic for you (mentalistic)

Substitutions

(3-5) Anymay, I think (anyway)

(3-6) is abung our panelists tonight (among)

Exchanges

(3-7) emeny (enemy)

(3-8) guinea kig page (pig cage)

Shifts

(3-9) State-lowned and - owned land (state-owned land)

(3-10) I did it myn ow way (my own way)

(Shattuck-Hufnagel, 1979, p. 299)

These five types of errors can be cross-classified as contextual vs. non-contextual errors. Contextual errors can be explained by reference to the utterance context. In most of them, a phonological segment is realized either too early or too late. Exchanges and shifts fall into this category, as well as many substitutions, which can be interpreted as anticipations or perseverations of sounds (examples (3-11) to (3-14)).

(3-11) the thirst thing (the first thing)
(3-12) wish a brush (with a brush)
(3-13) a phonological fool (a phonological rule)
(3-14) thick slack (thick slab)
(Fromkin, 1973, Appendix)

Certain omissions (examples (3-15) and (3-16)) have also been explained as contextual errors. The deletion of a segment is then said to be "triggered" by the presence of this segment elsewhere in the utterance (Shattuck-Hufnagel, 1979).

(3-15) two extra steps, one extra tep - step
(3-16) enclosed pease find (please)
(Shattuck-Hufnagel, 1979, p. 310 f.)

The remaining errors, which cannot be explained by reference to the utterance context, are called non-contextual errors. Most sound deletions and additions and many substitutions fall into this category.

3.2 The determination of the error units

A major issue in the analyses of sound errors is the linguistic classification of the error units, that is, the question of whether they can be classified in linguistic terms at all, and if so, how. This issue is pursued under the assumption that the error units correspond to planning units of phonological encoding. If, for example, the error units turned out to be syllables or phonological segments, one would conclude that the phonological representation is generated by retrieving and combining syllables or segments, respectively.

With very few exceptions (examples (3-27) and (3-28)), the error units can indeed readily be classified in linguistic terms. But it is not the case that all errors involve the same type of error unit. Examples (3-17) to (3-26) show that features, as well as single segments, clusters of segments, and syllables can function as error units.

Slips of single feature

(3-17) glear plue sky (clear blue sky)

(3-18) paratimes (paradigms)

Slips of single segments

(3-19) locket or ham (Hockett or Lamb)

(3-20) inner at date (dinner at eight)

Slips of segment clusters

(3-21) stedal peel guitar (pedal steel guitar)

(3-22) fleaky squoor (squeaky floor)

(3-23) serp is souved (soup is served)

(3-24) farlish argument (foolish argument)

Slips of syllables

(3-25) tremenly (tremendously)

(3-26) repetively (repetitively)

Others

(3-27) shrig souffle (shrimp and egg souffle)

(3-28) disteaching tingwer award (distinguished teaching award)

(Fromkin, 1973, Appendix)

However, not all of these units occur in slips of the tongue with equal frequency. In the large majority of the errors, the error unit is either a single segment or a cluster of two segments (Fromkin, 1971). Nooteboom (1969) analysed 815 Dutch sound errors and found that 90% of the errors were slips of single segments, 7% were slips of consonant clusters, and 3% were slips of other strings, including syllables (table 3.1).

Table 3.1: Error units in Nooteboom's (1969) corpus of sound errors

unit	number of errors	percentage of total
segment	729	90
consonant cluster	58	7
CV, VC, syllable and others	28	3
total	815	100

Similarly, in Shattuck-Hufnagel's (1983) English corpus of 210 sound exchanges, 66% of the errors were exchanges between single segments, and 28% were exchanges between two clusters or between a cluster and a single segment. 3% of the errors were exchanges between entire syllables. In 2% of the errors, the reversed strings were longer than a syllable. Finally, 1% of the errors were exchanges between single features (table 3.2).

Table 3.2: Error units in Shattuck-Hufnagel's (1983) corpus of sound exchanges

unit	number of errors	percentage of total
feature	2	1
segment	138	66
cluster (CC,CV,VC, less than a syllable)	59	28
syllable	6	3
string of segments (more than a syllable)	5	2
total	210	100

On the basis of these observations, a clear distinction can be made between syllables and features on the one hand, which rarely appear as error units, and single segments and clusters of segments on the other hand, which are quite likely to do so. Under the assumption that the error units correspond to planning units of phonological encoding, it can be concluded that the phonological representation is generated by retrieving and combining segments and segment clusters rather than syllables or features.

However, the statement that most errors are slips of single segments or clusters of segments fails to express an important regularity, namely that the error units tend to represent complete syllable constituents of the target words. First, consider those error units which comprise only one segment. Such error units either correspond to a complete syllable onset, nucleus, or coda of the target word (examples (3-29) and (3-30)), or they are part of a complex syllable constituent comprising more than one segment (examples (3-31) and (3-32)).

(3-29) mell wade (well made)
(3-30) Yoman Rakobson (Roman Jakobson)
(3-31) craperies cleaned (draperies cleaned)
(3-32) blake fruid (brake fluid)
(Fromkin, 1973, Appendix)

Unfortunately, no estimate is available of how often errors of each of these two types occur and how often one would expect them, given the distribution of simple and complex syllable constituents in the language. But an inspection of the published lists of sound errors suggests that the first type of error, in which the error unit corresponds to a complete syllable constituent, is by far the most frequent one. It has also repeatedly been reported that the segments constituting a complex syllable constituent are rarely separated in errors (MacKay, 1970; Shattuck-Hufnagel, 1983; Stemberger, 1983). Hence, the proportion of the single segment errors in which the error unit takes one of the positions of a complex syllable constituent in the target word must be small.

Sometimes, slips of the tongue are observed, in which a single segment replaces a cluster of segments (examples (3-33) and (3-34)). These errors can be viewed as complex errors consisting of a sound substitution and a deletion. But since the replaced clusters regularly correspond to complex syllable constituents, they can probably be described more naturally as errors affecting both the syllabic structure and the melody of the utterance: a complex syllable constituent is replaced by a simple constituent of the same type, to which one segment is associated. Thus, it can again be argued that the incorrect segment maps onto a complete syllable constituent of the word in which it appears.

(3-33) coat thrutting (throat cutting)
(3-34) it's a jew blay (it's a blue jay)
(Fromkin, 1973, Appendix)

Next, consider those errors in which two or more segments slip together. Again, it turns out that most of these strings correspond to complete syllable constituents (MacKay, 1972). Slips of onset clusters are observed most frequently (examples (3-35) and (3-36)), followed by slips of nuclei consisting of a vowel plus a glide or a liquid (examples (3-37) to (3-39)). Errors involving coda clusters are apparently quite rare, if they occur at all. Shattuck-Hufnagel's corpus includes 70 sound exchanges in which at least one of the two error units comprises more than one segment. 34 of these errors (or 49%) are exchanges between two onset clusters or between an onset cluster and a single onset consonant. 9 errors (or 13%) are exchanges between complex nuclei. Exchanges between coda clusters were not observed (see table 3.3).[1]

(3-35) clamage dame (damage claim)
(3-36) foon speeding (spoon feeding)
(Fromkin, 1973, Appendix)
(3-37) [meist] cases (most [moust])
(Stemberger, 1983, p. 140)
(3-38) first and girl to go (first and goal to go)
(Fromkin, 1973, Appendix)
(3-39) Is the merk bilning? (Is the milk burning?)
(Shattuck-Hufnagel, 1983, p. 115)

Occasionally, errors are observed in which the error unit consists of two complete adjacent syllable constituents, that is, an onset and a nucleus, or a nucleus and a coda, which do not correspond to a complete syllable. 16 out of 70 errors with complex error units (23%) in Shattuck-Hufnagel's corpus fall into this category (table 3.3). The nucleus and coda of a syllable, which constitute the rhyme, are more likely to form an error unit than the onset and the nucleus, although the frequencies of all of these errors are low.

Table 3.3: Nonsegmental error units in Shattuck-Hufnagel's corpus of sound errors

unit	number of errors	percentage of total
onset cluster	34	49
complex nucleus	9	13
CV (less than syllable)	4	6
VC (less than syllable)	12	17
syllable	6	9
string of segments (more than syllable)	5	7
total	70	100

(see Shattuck-Hufnagel, 1983, p. 116)

On the other hand, there are apparently no errors in which two segments belonging to different complex syllable constituents serve as error unit. For example, the second consonant of an onset cluster and the following vowel, or the liquid of a nucleus and the following consonant never form an error unit.

The coherence of syllable constituents is further supported by a related observation, which has already been mentioned above, namely that syllable constituents rarely break apart in errors. Shattuck-Hufnagel (1983) merely notes that this holds for the onset clusters as well as for the nuclei in her corpus, but she does not provide the respective error frequencies. Stemberger (1983) analysed English errors involving the syllable nucleus and reported that his corpus included far more errors where complex nuclei behaved as units than errors where their segments were separated. There were 122 errors in which the vowel and the following glide formed an error unit, as compared to only 9 errors (7%) where such a nucleus was broken up; and there were 107 errors in which the error unit consisted of a vowel plus a following liquid, as compared to 32 errors (23%) in which only one segment of such a nucleus served as error unit. When the vowel was followed by some other consonant, these two segments were misplaced together in only 48 errors and were separated in 959 errors (95%). No systematic evidence is available as to the coherence of coda clusters, presumably because errors involving this syllable constituent are not observed very often.

To summarize, in the majority of the sound errors, the error unit consists of a single segment or of a cluster of segments which corresponds to a complete syllable constituent. This suggests that those segments which map onto a common syllable constituent are retrieved together, whereas the segments of successive syllable constituents are retrieved independently of each other. Shattuck-Hufnagel (1983) calculated the proportions of the errors in her corpus which could be explained as slips of individual segments, as slips of the syllable constituents onset and rhyme, and as slips of the constituents onset, nucleus, and coda. About 50% of the errors, namely the exchanges between single consonants representing syllable onsets, could be explained under all three hypotheses. 66% of the errors could be described as slips of single segments, 71% as slips of onsets or rhymes, and 81% as slips of onsets, nuclei, or codas.

To conclude this section, it should be mentioned that, if the phonological representation is taken to be generated by retrieving and combining segments and segment clusters, one type of errors *cannot* be accounted for, namely feature errors (examples (3-40) and (3-41)). As has already been mentioned, such errors are rare (Shattuck-Hufnagel & Klatt, 1979), but they do occur and require an explanation.

(3-40) pig and vat (big and fat; voicing reversal)
(3-41) the marty will go on all tight (the party will go on all night; nasality reversal) (Fromkin, 1973, Appendix)

To assign feature errors to the phonological level, one must posit that the phonological representation is generated by retrieving and combining individual features. But then the question arises of why errors involving entire segments arise more frequently than features errors. Alternatively, one can maintain the claim that the units of phonological encoding are single segments and clusters of segments and assume that the *phonetic* representation is generated out of individual features. Feature errors can then be said to arise during the phonetic encoding of the utterance. Admittedly, no empirical evidence is available so far to defend this allocation of the feature errors. But it should be noted that there are independent linguistic arguments for the claim that the phonological representation of a word includes a tier whose units are phonological segments defined as feature *bundles* and that in the derivation of the phonetic representation this tier is decomposed into subtiers each of which corresponds to one feature (Browman & Goldstein, 1986; Hayes, 1986; Mohanan, 1986; see also chapter 2).[2]

3.3 The positional constraint on sound errors

In section 3.1, exchanges, shifts, anticipations, and perseverations of sounds were described as ordering errors. They are observed when intended segments are realized in incorrect locations. In an exchange, for instance, two target segments or clusters leave their appropriate locations, each of them taking the position meant for the other segment or cluster. Shattuck-Hufnagel (1979, 1983) has pointed out that this description is based on two important presuppositions. First, the positions of the segments in the utterance must be specified independently of the segments themselves; otherwise, it makes little sense to say that segments take inappropriate positions. Second, phonological encoding must include a mapping process which assigns segments to positions. One cannot describe errors as incorrect associations of segments to positions without regarding the normal process of phonological encoding as assignment of segments to appropriate positions in the utterance. Thus, in Shattuck-Hufnagel's theory, phonological encoding includes three steps: the phonological segments of an utterance are retrieved, a frame of positions is generated, and the segments are associated to these positions.

Important evidence concerning the nature of this frame is provided by the so-called positional constraint on sound errors. Boomer and Laver (1968) describe it in their fifth law:

> Segmental slips obey a structural law with regard to syllable-place; that is, initial

> segments in the origin syllable replace initial segments in the target syllable, nuclear replace nuclear and final replace final. (p. 7)

The positional constraint applies not only to anticipations (example (3-42)) and perseverations (example (3-43)), but also to exchanges (example (3-44)) and shifts (example (3-45)).

(3-42) if you can change the pirst part (first)
(Shattuck-Hufnagel, 1979, p. 300)
(3-43) ricotta cheese chause (cheese sauce)
(Shattuck-Hufnagel, 1987, p. 32)
(3-44) It's past fassing - fast passing by.
(3-45) most claudal side (caudal slide)
(Shattuck-Hufnagel, 1979, p. 299)

Confirming evidence for the positional constraint has been reported in virtually every analysis of speech errors (Fromkin, 1971; Garrett, 1975, 1980; MacKay, 1970; Nooteboom, 1969; Shattuck-Hufnagel, 1979, 1983, 1987), and the percentage of errors in which it is violated is small. For example, Fromkin (1971) found two violations in a corpus of 600 speech errors. Nooteboom (1969) analysed 546 slips of consonants and consonant clusters and did not find a single violation. Shattuck-Hufnagel (1979) found four violations in 210 exchange errors, but she also noted that the constraint was violated much more frequently, in about 30% of the errors, in sound anticipations and perserverations. Still, there is ample evidence that the positional constraint is observed in the majority of the errors.

Thus, a misplaced segment typically moves from its target position to the corresponding position in another syllable. An important implication of this observation is that the phonological representation generated in language production must include a description of the syllabic structure of the utterance. Shattuck-Hufnagel assumes that it is encoded in the frame to whose positions the segments are associated. In other words, the positions of the frame can be regarded as syllable constituents.

This proposal presupposes that the positional constraint is best captured by reference to the syllabic structure of the utterance. However, alternativate accounts of the constraint have been suggested. First, there are practically no errors in which a vowel takes the position of a consonant or vice versa. This *can* be taken as evidence for a syllable-based constraint. Apparently, the "landing sites" of misplaced vowels and consonants are confined to those positions which are marked in the syllable template as suitable for vowels and consonants, respectively. But it has often been observed that the segments which participate in a contextual error tend to be phonologically similar, sharing more features than would be expected on the basis of a chance estimate (Fay & Cutler, 1977; Fromkin, 1971; Garrett, 1975; Nooteboom, 1969; Shattuck-Hufnagel & Klatt, 1979). The strong tendency of vowels to replace vowels and of consonants to replace consonants might just be an instance of this general tendency of sound errors to involve similar segments (MacKay, 1970). Note, however, that this phonemic similarity constraint does not rule out exchanges between onset and coda consonants.

Second, word-initial consonants are much more likely to slip than consonants in other word positions. I will refer to this observation as the initialness effect. Shattuck-Hufnagel (1987) reported that 66% of the 1520 slips of consonants or consonant clusters in her corpus occurred in word onset positions, whereas only 33 % of all consonants in normal adult speech appear word-initially (Carterette & Jones, 1974). In monosyllabic words, the syllable onset and the word onset obviously coincide, but in polysyllabic words, the word onset consonants are also more likely to be involved in errors than the consonants in other positions. In adult speech, only 19% of all consonants in polysyllabic words appear word-initially, but in Shattuck-Hufnagel's corpus 442 out of 793 consonant errors involving polysyllabic target words (or 56%) occurred there. Moreover, in most contextual errors, both segments or clusters participating in the error stem from word-initial positions.

In the majority of the sound exchanges, for instance, two word-initial consonants exchange positions rather than one word onset and one word-internal consonant. Again, this holds for monosyllablic as well as for polysyllabic words. In Shattuck-Hufnagel's corpus, 89 out of 103 consonant exchanges between monosyllabic words (or 86%) and 76 out of 84 consonant exchanges between polysyllabic words (or 91%) involved two word onsets, whereas only 50% of the consonants in monosyllabic words and, as was mentioned, 19% of the consonants in polysyllabic words appear word-initially in normal adult speech. The positional constraint in all of these errors can be explained by reference to the word position: word-initial consonants are particularly likely to participate in errors, and they tend to interact with each other rather than with word-internal or word-final segments (Garrett, 1975, 1980).[3]

Evidence for a positional constraint on consonant errors which cannot be explained by reference to the initialness effect could come from contextual errors which involve at least one word-internal or word-final consonant. Some examples are given in (3-46) to (3-51). Unfortunately, such errors are rare, and no estimate is available of how many of them violate or obey the syllable-based constraint. At any rate, the syllable-based constraint has been reported to be fairly strong, and there is no indication that it is massively violated in slips of word-internal or word-final segments.

(3-46) of sub observations (of such observations)
(3-47) furger surgery (further surgery)
(3-48) enchire chapter (entire chapter)
(3-49) Andela Javis (Angela Davis)
(3-50) god to seen (gone to seed)
(3-51) cuff of coffee (cup of coffee)
(Fromkin, 1973, Appendix)

Thus, the positional constraint on sound errors can be captured in at least three different ways, by reference to the syllabic structure of the utterance (syllable-based constraint), by reference to the phonological similarity of the slipping segments (similarity constraint), and by reference to the word positions of the error units (word-based constraint). Clearly, none of these formulations is completely satisfactory. The first and second account fail to mention the initialness effect, whereas the third only covers slips of word-initial consonants and fails completely to constrain the positions of misplaced word-internal or word-final segments. It does not even rule out exchanges between vowels and consonants, which are rarely observed.

The empirical findings can probably best be covered by a combination of two of these constraints, namely the word-based constraint and either the syllable-based constraint or the similarity constraint. Both of the latter two constraints rule out interactions between vowels and consonants. In addition, the syllable-based constraint also prohibits onset consonants from taking coda positions and coda consonants from moving into onset positions. Whether or not this is necessary remains to be seen.

On theoretical grounds, it can be argued that the word-based constraint is better compatible with the syllable-based constraint than with the similarity constraint because the former two constraints both refer to the syllabic structure of the utterance, whereas the latter doesn't. As Shattuck-Hufnagel (1987) has pointed out, the word-based constraint does not refer to the segment in the absolute word-initial position, which can either be a vowel or a consonant. Instead, it is on the one hand confined to word-initial *consonants*, and on the other hand, it refers to *all* consonants of the word onset and not only to the first one. This implies that the onset of the word-initial syllable must be distinguished from the remaining word positions. From here, it is a small step to assume that the syllabic structure of the entire word is represented, providing the basis for the syllable-based constraint.[4] This suggestion is supported by the observation discussed in the last section that the error units tend to correspond to complete syllable constituents of the target word. As far as I can see, this holds not only for errors involving word onsets, but also for errors in which the error unit appears in a word-internal or word-final position.

Hence, I assume that the positional constraint is based on a description of the syllabic structure of the word, as Boomer and Laver's (1968) formulation of the constraint implies, and that for independent reasons word-initial consonants are particularly likely to slip and to interact with each other.

3.4 Summary and conclusions

In section 3.2, it was examined how the error units in sound errors could best be described. The majority of the errors turned out to involve either a single segment or a cluster of segments typically corresponding to a complete syllable constituent. Under the assumption that the error units correspond to planning units of phonological encoding, it can be concluded that word forms are generated by retrieving and combining segments and segment clusters. Those segments which map onto a common syllable constituent are retrieved together and are therefore likely to form an error unit, whereas those which are associated to different constituents are selected independently of each other and do not tend to form an error unit.

Section 3.3 discussed the positional constraint on sound errors, that is, the tendency of misplaced segments to take new positions which are similar to their target positions. It was argued that this constraint can, to a large extent, be captured by reference to the syllabic structure of the word. Segments are likely to move from their appropriate positions to corresponding positions in other syllables. However, this formulation of the positional constraint does not cover the observation that word-initial consonants are particularly likely to participate in errors and tend to interact with each other rather than with consonants in other word positions. This initialness effect must be explained by a separate principle.

In chapter 2, an outline was provided of how the phonological representation of a word is conceptualized in nonlinear phonology. Recall that the phonological representation is viewed as a multi-layered object, which includes a description of the melody of the word as well as a specification of its syllabic structure. The melody and the syllabic structure are captured in independent tiers.

The assumption that the phonological representation which is generated in language production is, by-and-large, structured as proposed in the nonlinear framework is supported by the speech error evidence. The error units are phonological segments, that is, units of the segmental melody tier. The observation that they usually correspond to syllable constituents and that they obey the positional constraint can be viewed as evidence for the assumption that the syllabic structure of the word is also represented and affects the process of phonological encoding. Furthermore, the speech errors show that the units of the melody tier are functionally different from those of the syllabic structure. Phonological segments function as error units, whereas the syllabic structure determines which segments tend to be selected incorrectly or to be misplaced together and which new positions they are likely to take.

The speech error evidence just reviewed is often regarded as a "body of facts" which any model of phonological encoding minimally has to explain. Two models which are virtually tailored to do so will be introduced in the next chapter. First, Shattuck-Hufnagel's model, which has already been alluded to, will be described more systematically, followed by an overview of Dell's spreading activation model of phonological encoding.

Notes

1. The corresponding information for Nooteboom's corpus is not available.

2. Chomsky and Halle (1968) regarded both the phonological and the phonetic levels of representation as each corresponding to a single sequence of segments, with each segment being defined as a set of feature values. The bundling of features to segments implies that all features have the same scope and are perfectly aligned with each other. This assumption can be defended for most phonological features, but it is problematic on the phonetic level. A well-known consequence of misalignement between phonetic features is, for instance, the stop-insertion in English between

a nasal or labial and a following fricative, e.g. in "prince" [nts] (Fourakis, 1980). The airflow is completely stopped for a moment because the soft palate is raised slightly prior to the release of the contact between the alveolar ridge and the tip of the tongue. Such phenomena require a more precise description of the temporal coordination between gestures than can be given in the segmental framework. Also, languages differ in the temporal coordination between gestures. Hence, the timing of gestures is linguistically relevant, at least for the description of differences between languages, and cannot be relegated to the (universal) domain of motor implementation of the gestures (Ladefoged, 1980). Mohanan (1986) suggests a phonetic representation in which the features are independently represented, as segments in their own right, and are directly associated to the positions of the skeletal tier. Within such a framework the details of the temporal coordination between features can be captured. Similarly, Browman and Goldstein (1986) describe speech sounds in terms of the constellations of gestures which are involved in their production, that is, as independently specified movements of articulators or articulatory subsystems, which are spatially and temporally coordinated in specific ways.

3. The word-based constraint can in turn partially be captured by reference to the stress pattern of the target words. In English, word onset consonants are highly likely to be the onsets of the syllable which carries the main lexical stress of the word. In Shattuck-Hufnagel's (1987) corpus this was true for 69 out of 76 (or 91%) of the exchanged word onsets. There were only four exchanges of syllable onsets involving polysyllabic words in which the main stress did *not* fall on the initial syllable. The misplaced segments in all of these errors were the word onsets rather than the onsets of the syllable carrying the main stress. The results of an error elicitation experiment (Shattuck-Hufnagel, 1985b) also suggest that the positional constraint can be described more accurately by reference to the word position than by reference to the stress pattern of the target words.

4. Shattuck-Hufnagel (1987) proposes that at some point during the process of phonological encoding, the word form is represented in terms of two constituents, the word onset and the rest of the word. During this phase, the onset consonants are more likely to slip than the remaining consonants of the word, which are protected from slipping by their integration into the constituent "rest of the word". But since the constituents "word onset" and "rest of the word" are not supported by any independent evidence, I do not find this proposal particularly convincing.

4 The generation of the phonological representation

4.1 Shattuck-Hufnagel's "Scan-copier"

Shattuck-Hufnagel's (1979, 1983) model of phonological encoding belongs to the class of so-called "frame-and-slot models" of language production, according to which mental representations of utterances are created by associating linguistic items (such as morphemes, phonological segments, etc.) to the ordered slots of independently generated frames (Garrett, 1975; MacKay, 1982, 1987).

On the basis of her analysis of sound errors, Shattuck-Hufnagel concludes that the planning units of phonological encoding must either be individual phonological segments or the segments and segment clusters which map onto the syllable constituents onset, nucleus, and coda. The positional constraint on sound errors is taken to be based on a description of the syllabic structure of the utterance. Shattuck-Hufnagel represents syllables as frames, whose slots correspond to the syllable constituents onset, nucleus, and coda. When the phonological representation of an utterance is created, its segments (and clusters) are retrieved, the sequence of frames representing its syllabic structure is built up, and the segments (and clusters) are associated to the positions of the syllable frames.

Shattuck-Hufnagel's model presupposes the generation of the syllabic structure for a stretch of speech, probably corresponding to a phrase, and the retrieval of the segments (and clusters) and describes their association to the positions of the syllable frames. A scan-copier is proposed, which examines the set of retrieved units, determines the correct insert for each slot in the syllable frames, and copies the selected units into the corresponding slots. This is done sequentially, proceeding slot-by-slot from the beginning of the utterance to its end. As soon as a unit is selected, it is marked by a check-off monitor as "used". A second monitor inspects the generated sound sequence. It marks sequences which are likely to have arisen from errors and deletes or changes them.

The selection of the correct insert for a given slot is based on two criteria. First, each segment (and segment cluster) is specified as possible insert for one type of slot, that is, as a potential onset, nucleus, or coda unit. Consonants (and clusters) which may appear in two positions are represented as two units with differing positional specifications. In filling a certain position, the scan-copier restricts its search to those units which are destined for that type of position. In selecting an insert for an onset position, for example, it only considers those consonants (and clusters) which are labelled as onsets and ignores all segments (and clusters) which are marked as nucleus or coda.

Since the segments (and clusters) for a whole stretch of speech are retrieved together, the scan-copier must often decide between several suitable inserts for a given slot. These decisions are based on the second criterion, the serial order of the segments. The segments are not delivered to the scan-copier as an unordered set, but they are properly linearized, as they appear in the utterance, and are inserted into the slots of the syllable frames in that order. The first onset unit in the sequence is entered into the onset slot of the first syllable, the second onset unit into the onset slot of the second syllable, and so on.

Hence, the scan-copier associates an ordered set of sublexical units to the ordered slots of the syllable frames. Shattuck-Hufnagel (1979) refers to this aspect of her model as "one of the most interesting paradoxes revealed by speech errors" (p. 313). She notes that

> ... speech errors show clearly that single sound units can become misordered during the production process. The strong implication of this fact is that, counter to one's intuitions, the production process includes a serial-ordering mechanism for phoneme-sized segments. .... One proposal that suggests the storage of lexical items as sets of unordered segments is Wickelgren's (1966) context-sensitive phoneme theory. .... The alternative view maintained in this paper is that items are stored in the lexicon with their phonological segments in the proper order and retrieved from the lexicon in that form, but at some point during the production process these segments must be copied one-by-one into waiting ordered slots that have been computed independently. (p. 313 f.)

It is probably misleading to refer to the activity of the scan-copier as ordering since this implies that the phonological segments are unordered to begin with. As the name of the device indicates, the activity of the scan-copier is best described as copying; an ordered set of segments is copied one-by-one into an ordered set of slots. The obvious problem with this description is that the function of this process is quite unclear. In an extension of her model, Shattuck-Hufnagel (1987) proposes that phonological encoding might involve several processors, a lexical, a phrasal, and a motor processor, and that representations must be copied from one processor to the next. Since the model does not specify these processors very well, it is difficult to determine the implications of this proposal.

I will later suggest a model of phonological encoding which resembles Shattuck-Hufnagel's model in certain respects and which, in particular, also assumes that an ordered set of segments is mapped onto the ordered positions of a frame, but the function of this process is viewed differently.

4.2 Dell's spreading activation model of phonological encoding

A detailed model of phonological encoding has recently been proposed by Dell (1986).[1] Like Shattuck-Hufnagel's model, it is a frame-and-slot model; that is, phonological representations are created by inserting sublexical units into the ordered slots of independently generated frames. But whereas Shattuck-Hufnagel's model presupposes that the sublexical units for a stretch of speech have been selected and that the frames have been generated, Dell combines the frame-and-slot model with a spreading activation model specifying the selection of the sublexical units and the generation of the frames.

In a spreading activation model of language production (or comprehension), linguistic knowledge is represented in a network of interconnected nodes. Each node corresponds to a linguistic rule or to a lexical or sublexical unit. The nodes are processing units, which can be more or less activated. Activation spreads between them, that is, each node sends some proportion of its activation to the nodes it connects to, thereby increasing their activation levels, and receives some of their activation. Activation decays over time so that unbounded spread of activation from one node to all other nodes of the network is avoided. In generating a representation, adequate units and rules must be selected and combined. Which rules and units are chosen at a given moment depends largely on their momentary activation levels. Roughly speaking, a highly activated unit or rule is likely to be preferred over a less highly activated unit or rule of the same type (Anderson, 1976, 1983; McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982; Rumelhart & Norman, 1982).

In Dell's model, the linguistic units relevant for phonological encoding are morphemes, syllables, rhymes, phonological segments, clusters of segments, and features (figure 4.1). The nodes representing these units are connected to form a hierarchical structure, in which each unit is linked to its constituents. The segments and clusters are marked with respect to the syllable positions they may take, that is, as onset, nucleus, or coda units. Those segments and clusters which may appear both as syllable onsets and codas are represented twice with different positional specifications. The network includes "null-elements" which take the onset or coda positions in syllables beginning or ending in a vowel.

The only rule which is relevant in phonological encoding is the syllable rule, stating that a syllable includes the constituents onset, nucleus, and coda, appearing in that order. Whenever this rule is activated, it creates a frame with three ordered slots, corresponding to these three syllable constituents. It is important to note that the model includes this syllable *rule* as well as syllable *units*, which are part of the hierarchy of sublexical units and have specific segments or/and clusters as their subordinate nodes.

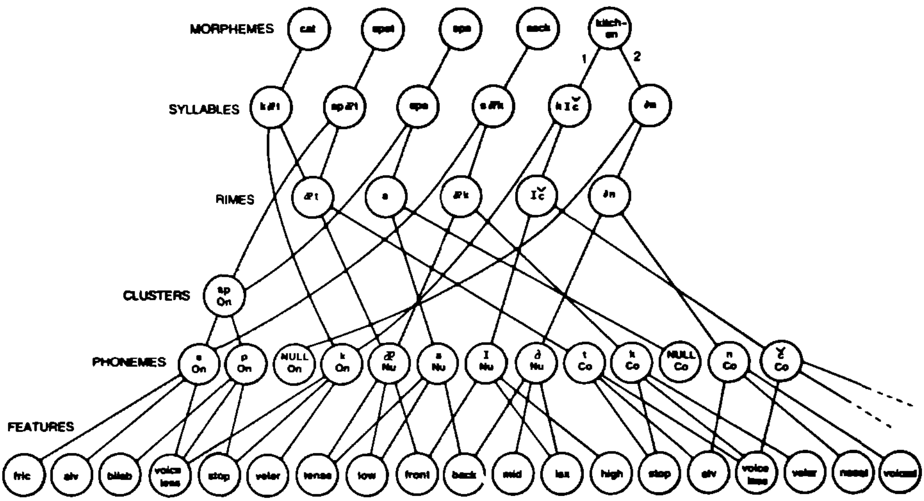


Figure 4.1 A piece of a network for phonological encoding (Dell, 1986, p 295)

When a phrase is phonologically encoded, activation spreads from its morphemes to their sublexical units Normally, several morpheme nodes, for example a noun and the following verb, are simultaneously activated to some degree from higher-level nodes and transmit some of their activation to their sublexical units From a monosyllabic morpheme, activation spreads to one syllable and its constituents, from a polysyllabic morpheme, it spreads to all of its syllables and to their constituents Many sublexical units which are not meant to be included in the utterance also receive some activation from activated superordinate or subordinate nodes

Hence, at any given moment, a large number of sublexical units is activated. Somehow, this activation pattern must be transformed into a phonological representation. It must be decided which sublexical units are to appear in the representation and in which order.

The selection and ordering of the sublexical units of an utterance can begin as soon as at least some of its morphemes (minimally one) have been selected and assigned to positions of the morphological representation. Then one of these morphemes is selected as the "current node". The item marked as first in the morphological representation is assigned current node status first. Later, the current node status is passed on to the second morpheme, then to the third, and so on.

When a morpheme is selected as the current node, it receives an extra boost of activation, through which it becomes more highly activated than all other morphemes. Since each node sends a fixed proportion of its activation to its neighbours, the sublexical units of the current morpheme also receive more activation than the sublexical units of all other morphemes. As the morphemes of a phrase become the current node one after the other according to their order in the utterance, their sublexical units reach their activation maximum in the same sequence, provided, of course, that no errors arise.

The current node principle applies not only to the morphemes of an utterance, but also to the syllables within polysyllabic morphemes. When such a morpheme is the current node, it transmits some of its activation to all of its syllables in parallel, as do the non-current morphemes. But in addition, one of its syllables is assigned current node status. This syllable is activated more strongly from the morpheme level than the remaining syllables; therefore, its segments and clusters are also activated particularly strongly. The syllables are selected as the current node one after the other, as they appear in the morpheme.

While activation is spreading from the morphemes to the sublexical units, the syllable rule is activated, over and over again, each time creating a frame with the ordered slots onset, nucleus, and coda. At certain time intervals, these slots are filled. As was noted above, each segment and cluster can only be associated to one type of syllable constituent and is marked accordingly. Each slot of the syllable frame is filled by the most highly activated segment or cluster of the respective category that can be found. The three slots of the syllable frame are filled in parallel. Upon their insertion into the frame, the selected sublexical units are tagged as being part of the phonological representation. Their activation level is immediately reduced to zero so that they will not be reselected over and over again. But since the tagged segments are still receiving some activation from activated superordinate and subordinate nodes, their activation level quickly rebounds from zero and then gradually decays.

When a monosyllabic morpheme is the current node, activation spreads strongly to its syllable node, and from there to the respective segments and clusters. They become more highly activated than all other segments and clusters and are inserted into the syllable frame. Then their activation decays, and the next morpheme is assigned current node status.

When a polysyllabic morpheme is the current node, the syllable frame is generated and filled repeatedly, once for each syllable of the morpheme. Each time, a different syllable unit is the current node, and a different set of onset, nucleus, and coda segments are found to be most highly activated and are inserted into the slots of the frame. When the syllable frame is filled for the first time, the first syllable is the current node; its segments are more highly activated than all other segments and are therefore entered into the slots of the frame. Then the current node status is transferred to the second syllable. When the syllable frame is generated for the second time and inserts are selected, the segments of the second syllable emerge as the most highly activated units and fill the slots, and so on.

Thus, the selection and linearization of the sublexical units is governed by two interacting mechanisms. Since the morphemes of an utterance as well as the syllables of a polysyllabic morpheme are assigned current node status in succession, their constituents reach their peak activation levels at different points in time and are selected in that order. In other words, the serial order of the morphemes and syllables in the phonological representation is determined by the temporal order in which they reach their activation maximum. The segments within a syllable, on the other hand, reach their maximal activation level more or less simultaneously. They are ordered by association to the ordered slots of the syllable frame. The insertion rule is encoded in the specifications carried by the segments and segment clusters and by the slots of the frame. The selected onset unit is associated to the onset slot, the nucleus unit to the nucleus slot, and the coda unit to the coda slot.

Dell discusses in detail how his model accounts for various speech error phenomena. In general, sound errors occur when incorrect segments reach higher levels of activation than the correct ones and are therefore selected. Contextual errors are due to interference among the segments of an utterance. For instance, a sound anticipation arises when a segment becomes too highly activated too quickly and is selected too early. Consider Dell's (1986, p. 292) example of the phonological encoding of the phrase

(4-1) Some swimmers sink.

While "some" is being phonologically encoded, the following morphemes are already activated to some extent and pass on some of their activation to their sublexical nodes. Since the vowel [I] is receiving some activation both from "swimmer" and from "sink", it becomes highly activated very rapidly. If it is more highly activated than [ʌ] at the moment when the syllable frame is to be filled for the first time, it is selected instead of the target segment, and a sound anticipation is observed.

Non-contextual errors arise in a similar way, except that in this instance, the segments which become too highly activated were not meant to be included in the utterance at all. While the speaker is preparing for the above phrase, for instance, the verb "drown" might also become somewhat activated, transmitting some of its activation to its segments. If its onset cluster is more highly activated than the onset consonant of "sink" at the moment when the verb is being phonologically encoded, it will be selected, resulting in the substitution error "drink".

Single segments and segment clusters are more likely to appear as error units than syllables and features because they represent the units which are selected and ordered during phonological encoding. Syllables and features become activated, but there are no selection and ordering processes for these units. It is more likely that only one segment or segment cluster is incorrectly selected than that wrong choices are made for several segments or clusters at the same time. Still, the nucleus and coda of a syllable have a slight tendency to slip together because they both connect to the rhyme unit and influence each other's activation level via spreading of activation through this node. It is less likely that all three constituents of a syllable are incorrectly selected at the same time. They have the syllable as common superordinate node, but since the nucleus and the coda unit are only indirectly connected to it via the rhyme, the activation levels of these two units on the one hand and of the onset unit on the other hand are less highly correlated than the activation levels of the segments constituting the rhyme.

The tendency of contextual errors to involve similar segments is due to feedback from features to segments. An activated segment node transmits some of its activation to its feature nodes, which in their turn activate all segments they connect to. Occasionally, when a segment sharing several features with a target segment receives some additional activation, say from another morpheme, it becomes more highly activated than the intended segment itself and replaces it. A segment which is only activated from the morpheme level, but does not share any phonological features with the target is less likely to become activated enough to replace the target segment.

Finally, the positional constraint on sound errors is explained by the assumption that the decision mechanism which selects the inserts for the slots of the syllable frame strictly sticks to the categorial constraints defined by the slots. For instance, when an onset slot is to be filled, only onset units are considered; therefore, an incorrect segment or cluster of that category might be selected, but not a segment which is marked as nucleus or coda.

4.3 The time course of phonological encoding

Both Shattuck-Hufnagel and Dell assume that during the phonological encoding of an utterance sublexical units are retrieved and mapped onto the slots of independently generated frames, representing the syllabic structure of the utterance. However, the mapping process is described somewhat differently in the two models.

According to Shattuck-Hufnagel, the syllabic structure for a stretch of speech, probably a phrase, is created, and simultaneously the corresponding sequence of phonological segments is retrieved. The slots of the syllable frames as well as the segments are already linearized according to their order in the utterance *before* they are associated to each other. Each slot is filled by one sublexical unit. This is done sequentially, slot-by-slot, proceeding from the beginning of the phrase to its end. The first sublexical unit of the string is copied into the first slot, the second unit into the second slot, and so on.

In Dell's model, the frames of successive syllables are created and filled sequentially. Phonological encoding is viewed as a cyclic process. An encoding cycle includes the generation of a syllable frame, the selection of an insert for each of its slots, and the mapping between the slots and the selected segments and clusters. Each segment is marked as a suitable insert for one of the three slots of the syllable frame. The segments are selected and associated to their positions in parallel. Since in each cycle a different syllable node is the current node, each time different onset, nucleus, and coda segments are found to be the most highly activated units in their respective categories and are selected as inserts for the slots of the frame.

Thus, according to both models the sound form of a polysyllabic word is generated in a sequence of processing steps, in which successive fragments of the word are encoded. Both models assume that the encoding proceeds from the beginning of a word to its end. But in Dell's model each processing step is devoted to the encoding of one syllable, whereas in Shattuck-Hufnagel's model only one slot of a syllable frame is filled in each processing step.

Both Shattuck-Hufnagel's and Dell's description of the time course of phonological encoding are quite plausible and follow naturally from other assumptions of their models. However, neither proposal is based on any empirical evidence. Sound errors show that phonological representations are generated by retrieving sublexical units and inserting them into the slots of independently created frames. But they reveal nothing about the temporal order in which different parts of a word are encoded. Maybe the slots are indeed filled strictly sequentially as Shattuck-Hufnagel proposes; or maybe the positions within each syllable are filled in parallel and those in different syllables sequentially, as Dell suggests. A third possibility is that none of these proposals is correct and that the sublexical units of *all* syllables of a word are activated at the same time and are inserted into their slots more or less synchronously.

The experimental research reported below is directed at the investigation of this issue. The first series of experiments tested whether successive syllables of a word are encoded one after the other, as both Shattuck-Hufnagel and Dell assume, or in parallel. The second and third series examined whether the sublexical units within a syllable are selected and associated to their slots in parallel, as Dell suggests, or sequentially, as proposed by Shattuck-Hufnagel.

The time course of phonological encoding was studied because it represents an interesting issue in its own right. Apart from this, the experimental findings might help to constrain possible models of phonological encoding. Their relevance for the processing assumptions of such models is obvious. But evidence about the time course of phonological encoding can also have implications for the structural assumptions of a production model, in particular for the definition of the sublexical units. Dell assumes that tautosyllabic segments are inserted into their slots in parallel. In order to ensure that each segment is associated to the appropriate position, he posits that the segments carry labels indicating their places in the syllable. The segments of different syllables are taken to be selected in separate encoding cycles. Whether a segment appears in the first, second, or third syllable of a word depends on whether it is selected during the first, second, or third encoding cycle. But if it turns out that *all* segments of a word, rather than only those of one syllable, are activated simultaneously and are inserted into their slots in parallel, their specifications must be extended. In this case, each segment must not only be marked with respect to its position within a syllable, but it must also be indicated which syllable it belongs to.

Conversely, if the sublexical units of a word are activated strictly sequentially, as they appear in the word, and are mapped onto the slots of the syllable frames in that order, no additional specifications of their positions within a syllable or within the word are necessary because their serial order is already defined by the temporal order of their activation. Under the assumption that each slot is filled by one unit, the association of the units to the slots is also unambiguously determined. The unit which is activated first takes the first position, the unit which is activated next is associated to the second position, and so on. Since the positional specification of the segments is only assumed to explain how simultaneously activated segments are associated to the appropriate slots of the frame and is not supported by any independent evidence, it can be given up if it turns out to be unnecessary.

Finally, evidence concerning the time course of phonological encoding might also lead to a reconsideration of the notion of frames to whose slots the segments are said to be associated. If the segments are selected sequentially, there is no need to order them by mapping them onto the positions of frames, and one might wonder whether it is at all necessary to assume such frames. In chapter 3, the speech error evidence was discussed which is usually taken to provide support for the notion of the frames. But this evidence is certainly open to alternative interpretations. Moreover, it can be argued that speech error evidence alone is insufficient to postulate frames and a process associating segments to their slots if the functions of the frames and of the association cannot be specified.

However, the linguistic description of the phonological representation suggests that the notion of the frames should probably be maintained, even if it is not necessary for the linearization of the segments (chapter 2). One can think of the slots of the frames as the terminal positions of the syllabic structure of the word, which is an important level of representation in its own right, governing, among other things, the stress pattern of the word. According to this view the insertion of segments into the slots of the frames is not a process by which the segments are ordered, but an integrative process by which two complete and fully ordered representations, the melody and the syllabic structure of the word, are combined.

Note

1. Dell proposes a general model of sentence production, but only the phonological component of the model will be treated here. Other connectionist models of sentence production have been proposed, for example by Stemberger (1985a,b) and by MacKay (1987). In Stemberger's model, the phonological component is less well specified than in Dell's. MacKay's theory, on the other hand, seems overly complex, at least for the present purposes. Both MacKay's and Dell's model include several types of sublexical units, such as syllables, syllable constituents, segments, and features. In Dell's model, only segments and clusters are selected and ordered. Thus, only one phonological representation is generated. MacKay assumes that not only segments and clusters, but also smaller and larger sublexical units must be selected and linearized. Furthermore, in Dell's model activation spreads between the nodes and decays passively over time. MacKay's model includes two types of excitatory processes among nodes at different levels (spreading of priming and spreading of activation) and mutual inhibition among nodes within a level. So far, empirical evidence that would allow one to decide between these models is missing. The predictions for the experiments reported below are based on Dell's model.

5 The implicit priming paradigm

In the experiments which are reported below a new paradigm, called the "implicit priming paradigm", was used. In this chapter, I will first provide an outline of the paradigm and discuss the main prediction. Taking the first two experiments as examples, I will illustrate how the paradigm can be used to study the time course of phonological encoding. Subsequently, the experimental method will be described in detail.

5.1 Outline of the paradigm

The implicit priming paradigm made use of a paired-associate learning task. First, the subject learned five word pairs, for instance those listed under (5-1).

(5-1)

touw	kabel	(rope	cable)
poes	kater	(puss	tomcat)
woning	kamer	(house	room)
sjeik	kalief	(sheik	caliph)
peddel	kano	(paddle	cano)

In each of the following test trials, the first (left-hand) member of one of the pairs was presented as a prompt, to which the subject reacted by naming the second member of that pair, the response word, as quickly as possible. The response latency, defined as the interval between the onset of the prompt and the speech onset, was the main dependent variable in the experiment. The items were tested five times each in a random order. Then the subject was given performance feedback and went on to study the next group of word pairs, which was subsequently tested in the same way. In each block, only those items were tested which had been studied immediately prior to that block.[1]

The stimulus materials consisted of a practice set and five experimental sets of five word pairs each. The crucial characteristic of the experimental sets was the systematic phonological relationship between their response words. In experiment 1, for instance, the response words within each set shared the first syllable. All response words of set 1 started in /boe/, those of set 2 all started in /ka/, and so on (table 5.1).[2] In experiment 2, the response words within each set shared the second syllable.

Table 5.1: Stimuli of experiment 1

1	/boe/	2	/ka/	3	/le/
straf	boete	touw	kabel	docent	lezing
roof	boeven	poes	kater	pokken	lepra
reis	boeking	woning	kamer	vork	lepel
huisraad	boedel	sjeik	kalief	soldaat	leger
vrouw	boezem	peddel	kano	dood	leven
4	/po/	5	/si/		
bridge	poker	cola	sinas		
doel	poging	fluit	citer		
stoel	poten	graan	silo		
stand	pose	vezel	sisal		
contract	polis	ring	sieraad		

Note: Each set represents the stimuli for one homogeneous test block (blocks 1 to 5).

The experimental word pairs were tested under two conditions, in so-called *homogeneous* and *heterogeneous* blocks. In the homogeneous condition, the group of word pairs which was presented to the subject prior to a test block and which was subsequently tested consisted of the five items of one experimental set. In the heterogeneous condition, the same 25 word pairs were used, but in each heterogeneous block one word pair from each of the experimental sets was tested (table 5.2). Thus, in the homogeneous condition, the word pairs of a set were tested together in a block, and the response words of a block were systematically related in their forms. In the heterogeneous condition, the word pairs of each set were distributed over five different test blocks, and the response words within a block were not systematically related in their forms. Note that each prompt was associated with the same response word in both test blocks in which it appeared. Each of the ten test blocks was repeated three times.

Table 5.2: Combination of the experimental items in the heterogeneous test blocks (blocks 6 to 10)

6		7		8	
straf	boete	roof	boeven	reis	boeking
touw	kabel	poes	kater	huis	kamer
docent	lezing	pokken	lepra	vork	lepel
bridge	poker	doel	poging	stoel	poten
cola	sinas	fluit	citer	graan	silo

9		10	
huisraad	boedel	vrouw	boezem
sjeik	kalief	peddel	kano
soldaat	leger	dood	leven
stand	pose	contract	polis
vezel	sisal	ring	sieraad

5.2 Prediction

In the homogeneous test blocks, the invariance across the response words provided the subject with reliable information about the form of each individual response word. She could not predict which of the five response words would be correct in a given trial, but she knew that it would include certain phonological segments in certain positions. For example, when the first homogeneous set of experiment 1 was tested, she knew that all response words would begin in /boe/. No such information was given in the heterogeneous blocks.

The homogeneous and the heterogenous test condition bear some similarity to the related and neutral condition in a standard priming experiment (Brown, 1979; Carr et al., 1982; de Groot, 1983; Huttenlocher & Kubicek, 1983; Jakimik et al., 1985; McCauley et al., 1976, 1980; Pisoni et al., 1985; Slowiazek et al., 1987; Sperber, 1979; Tanenhaus et al., 1985). In such an experiment, the subject is presented with a series of target words or pictures, to which she must react as quickly as possible, typically by naming them or by classifying them in a certain way, for example with respect to their semantic category. Each target is preceded by a prime word, which can be semantically or phonologically related to the target (as in "dog-cat" or "cap-cat"), unrelated to it (as in "nurse-cat"), or neutral (as in "xxx-cat"). In the related conditions, the prime provides the subject with information concerning the form or the meaning of the upcoming target. In the *implicit* priming experiments, information about the form of the target was conveyed indirectly, by the invariance across the response words in a homogeneous test block, rather than by a separate preceding prime. The string which the response words of a homogeneous set had in common is called the *implicit prime.*

In standard priming experiments, the related primes tend to facilitate the reaction to the targets relative to the neutral primes; that is, the subjects react faster or/and make less errors. With respect to the response latency, the same result was expected for the implicit priming experiments, at least for certain types of primes (see below). The mean reaction time should be shorter in the homogeneous than in the heterogeneous test condition. Since the task is fairly simple, few errors should occur in either condition.

The prediction concerning the mean reaction times is based on the assumption that the subjects will use the implicit prime to prepare for the utterance. Consider the situation in a test block in which all response words begin with the same syllable. The subjects are certainly aware of the similarity between the response words. Most likely, they rehearse the recurrent string, assuming that this will speed their reactions.

Within the framework of Dell's model, this rehearsal can be described as a recursive process, in which the same syllable is encoded over and over again. In each encoding cycle, the syllable frame is generated, and its slots are filled by the primed phonological segments (see also Baddeley et al., 1975). At the end of each cycle, the activation level of these segments momentarily drops to zero, but they are immediatedly reactivated and selected again in the next cycle. Thus, the recurrent segments are kept in a state of hightened activation.

While this is going on, the prompt is read, and the response word is selected. Activation spreads from the selected morpheme to its syllables and their segments. The first syllable of the response word (that is, the syllable which was rehearsed before) is assigned the current node status first and receives more activation from the morpheme node than the following syllable. Its segments are selected one more time as inserts for the syllable frame. Then their activation decays, and the second syllable becomes the current syllable. In the following encoding cycle, the segments of that syllable are inserted into the frame.

Intuition suggests that the rehearsal of the primed syllable should facilitate the encoding of the response words. Since the segments of the first syllable are already highly activated at the beginning of the encoding cycle, they should be selected more rapidly, and the response latency should be shorter than in a control condition without rehearsal.

This expectation is based on the supposition that the length of the encoding cycle depends on how rapidly the segments reach a certain level of activation. In other words, it is assumed that the encoding of a syllable is terminated as soon as the activation of its segments exceeds a certain threshold.

Dell's model does not include such a threshold. Instead, Dell assumes that within a stretch of speech, a constant time span is devoted to the encoding of each syllable. Activation spreads from the morpheme nodes to the phonological segments, and at fixed time-intervals, their activation levels are inspected, and the most highly activated onset, nucleus, and coda unit that can be found are selected. The encoding time per syllable might vary across utterances, resulting in different speech rates, but once a certain rate has been selected, the same amount of time is allotted to each syllable.

I do not follow Dell here, but assume that the encoding cycle of a syllable ends as soon as the activation level of one onset, nucleus, and coda unit has reached a certain threshold. Then these segments are inserted into the slots of the syllable frame, and their activation level drops to zero. Differences in speech rate can be represented in terms of the selected threshold. The lower the threshold, the faster it is reached by the segments, and the shorter is the duration of the encoding cycles. If the segments of an utterance do not vary greatly in their activation levels at the beginning of the phonological encoding, the encoding cycles will be fairly regular, just as Dell proposes.[3]

The selection threshold is introduced here to capture the idea that the encoding time per syllable should *not* be a constant, but should depend on how quickly the phonological segments become activated. If this assumption is correct, the preactivation of the segments of the first syllable should reduce the duration of the first encoding cycle. This should manifest itself in a decrease of the mean reaction time relative to the control condition. In other words, it is predicted that the mean response latency should be shorter in the homogeneous than in the heterogeneous blocks.[4]

However, not all types of primes should be equally efficient. Some of them should, in fact, not affect the reaction times at all. The central assumption underlying the below experiments is that certain types of implicit primes should vary systematically in their effects on the response latencies, and, moreover, that these differences provide evidence concerning the temporal order in which different parts of a word are phonologically encoded.

As an illustration for the general line of the argument, consider the first two experiments. In experiment 1, the response words were implicitly primed by their *first* syllable, and the mean reaction time was predicted to be shorter in the homogeneous than in the heterogeneous blocks. In experiment 2, the response words were primed by their *second* syllable. One might expect the same result as for experiment 1. Again, the segments of one syllable can be rehearsed, whereby they become preactivated and can be selected particularly quickly. However, Dell's model makes a different prediction, namely that the preactivation of the segments of the second syllable should interfere with the phonological encoding of the first syllable; therefore, the rehearsal of the second syllable should delay the response rather than speed it up.

To see why this should be the case, consider first the control situation, in which no implicit prime is given. When the phonological encoding of the response word begins, the activation spreads preferentially to its first syllable, but also, though less strongly, to the second syllable. In order to respond quickly, the subject must choose a low selection threshold, which is reached by the segments of the first syllable after a short time-interval. At that moment, the segments of the second syllable are considerably less highly activated because they have so far received much less activation from the morpheme node.

Now consider the situation in which the second syllable is rehearsed. At the beginning of the phonological encoding of the response word, the activation again spreads preferentially to the first syllable. But since the segments of the second syllable are preactivated and are receiving further activation from the morpheme node, they will for quite a while remain more highly activated than those of the first syllable. If the same low selection threshold is chosen as in the control condition, it is likely that an error will arise, where the rehearsed segments of the second syllable fill the slots of the first frame, because they are still activated above that threshold, while the activation level of the segments of the first syllable have not yet reached it. Thus, a higher threshold must be selected than in the control condition, which will eventually be reached by the segments of the first syllable, but not by those of the second syllable. Therefore, the encoding of the first syllable will take longer than in the control condition. In the meantime, the extra activation of the segments of the second syllable, which was built up during the rehearsal, decays. Moreover, since a higher selection threshold has been chosen than in the control condition, it is unclear whether the second syllable can be encoded any faster than if it had not been rehearsed at all.

Thus, the preactivation of the segments of the second syllable should lead to massive interference in the encoding of the first syllable and to little or no facilitation in the encoding of the second syllable. If the subject wants to react quickly, she should *not* rehearse the second syllable of the response words, but should simply ignore the fact that the response words share that syllable. Then the mean reaction times in the homogeneous and in the heterogeneous blocks should be identical.

To summarize, if a subject rehearses an implicit prime, the primed phonological segments should become preactivated and should reach a given selection threshold particularly rapidly. Whether or not this facilitates the phonological encoding of the response words should depend on the word position of the prime. If the first syllable is rehearsed, its segments should be selected more rapidly than in the control situation, whereby the duration of the first encoding cycle should be reduced, and the response should be speeded. But if the second syllable is rehearsed, the preactivation of its segments should interfere with the encoding of the first syllable; therefore, the selection threshold must be raised relative to the control condition, and the encoding of the response words should be slowed down rather than facilitated. The reason why implicit primes consisting of the first or second syllable of the response words should differ in their effects is that, at least according to Dell's theory, the syllables of a word must be encoded sequentially, as they appear in the utterance. Preactivation of a given string of segments should interfere with the selection of those segments which must be selected prior to the preactivated ones. Therefore, the efficiency of implicit primes in various word positions can be taken as a basis for inferences about the temporal order in which different parts of a word are phonologically encoded.

Finally, it should be noted that the implicit primes can only facilitate the phonological encoding, but not the selection of the response words. In the homogeneous as well as the heterogeneous blocks, one out of five response words must be chosen in each trial, and the implicit primes can obviously not facilitate this selection. Hence, potential priming effects can be assigned fairly unambiguously to the level of phonological encoding.[5] In addition, primes which include the beginning of the response words allow the subject to prepare herself for the utterance on the articulatory level. When all response words begin with the same syllable, she can bring her speech organs in an optimal starting position between the trials, rather than keeping them in a neutral position, and this might speed the reaction. I will later discuss how the effects of phonological facilitation and of articulatory preparation can be separated.

5.3 Method

5.3.1 Subjects

Each experiment was run with ten subjects, four to six women and four to six men. All subjects were undergraduates at the University of Nijmegen and native speakers of Dutch. They were paid Dfl. 10,- each for their participation in the experiment.

5.3.2 Stimuli

The stimulus materials for one experiment consisted of a practice set and five experimental sets. Each set included five word pairs.[6]

The materials were constructed as follows: first, the response words for the five experimental sets were selected. Only common nouns of Dutch were considered, that is, nouns which were judged by three independent raters as "very likely to be known by the subjects". Since the choice of the response words was narrowly constrained by other criteria, it was not possible to use only words for which frequency counts are available. With few exceptions, the citation forms of the words were used. The response words of an experiment usually had the same number of syllables and the same stress pattern. Within each set, the response words shared one or more phonological segments in identical positions. These segments represented the implicit primes. Otherwise, the response words in a set were chosen to be as dissimilar in their word forms as possible. Ideally, no two response words of a set should share a syllable onset or a rhyme which was not meant to be primed, but this constraint could not always be met. Finally, there should be no obvious semantic relationships between the response words of a set. For the practice set, five phonologically and semantically unrelated response words were selected.

Next, the response words were coupled with prompts. Each prompt should be semantically related to the response word with which it was coupled and unrelated to all other response words so that the items would be easy to learn. Various types of semantic relationships were realized in the stimulus materials. Word pairs forming lexicalized compounds were avoided.

Then it was determined which word pairs were to be tested together in each of the five heterogeneous blocks. In each of these blocks, one item from each set was tested. The items were combined such that the response words of a block were not semantically or phonologically related to each other and that each prompt was only semantically related to the corresponding response word, but not to any of the other response words of the block.

The word pairs differed from each other in many ways, for example, in the frequency of the two words and in the type of semantic relationship holding between them. It should be noted again that each word pair was tested in a homogeneous *and* in a heterogeneous block. Therefore, all effects of characteristics of individual items were kept constant across these test conditions.

5.3.3 Apparatus

The experiment was controlled by a Miro GD laboratory computer. Visual information was presented to the subject on an electronic display connected to the computer. Warning tones were played over Sennheiser HD414 headphones. The onset of the subject's response to a prompt was registered by a Sennheiser MD211N microphone and a voice-operated relay interfaced with the computer. The session was taped using a Revox A700 recorder. The experimenter sat in the same room as the subject and could overhear her responses. The information on the subject's screen, the correct response word for each trial, and the subject's reaction times were displayed to the experimenter on a second screen out of sight of the subject.

A possible objection against the use of the voice key is that it is likely to react to incomparable events when response words with different initial segments are uttered and that the corresponding reaction times cannot be unambiguously interpreted. Since the same word pairs were tested in the homogeneous and in the heterogeneous blocks, this argument is not relevant for the evaluation of the effect of the two types of test blocks. Reaction time differences between word pairs were not interpreted.

5.3.4 Design

The design included four within-subject factors. Each word pair was tested in one homogeneous and in one heterogeneous block. These two types of test contexts represented the levels of the first factor, "contexts". The effect of this factor is called "context effect" or, synonymously, "priming effect". The 25 items formed five sets of pairs with phonologically related response words. These sets corresponded to the levels of the factor "sets". Each test block was administered three times, and "repetitions" was the third factor. Finally, each word pair was tested five times within each block; hence, there was a factor "trials" with five levels.

In addition, the design included one between-subjects factor, "groups", with two levels. The group distinction was introduced in order to control for the sequence of homogeneous and heterogeneous test blocks. The experimental session included a practice block and a series of 30 experimental blocks, which was divided into three parts of 10 blocks each. Within each part, each of the five homogeneous and each of the five heterogeneous blocks was administered once. In group 1, the first five blocks of each part were homogeneous, and the remaining ones were heterogeneous; in group 2, the items were first tested in heterogeneous and then in homogeneous blocks.

The five homogeneous and the five heterogeneous blocks were administered in a different random order to each subject in each of the three parts of the experiments. Each word pair was tested five times within each block. The order of the items was random, except that repetitions of word pairs in successive trials were avoided. A new random sequence was generated for each subject and for each of the 30 blocks.

5.3.5 Procedure

The subjects were tested individually. At the beginning of the experiment, the subject was seated in a dimly lit room in front of a monitor, at a distance of about .70 m. She was handed an instruction sheet and was asked to read it carefully. If necessary, questions were answered by the experimenter. Then the practice block was administered, followed by the 30 experimental blocks.

The experiment consisted of alternating presentation and test phases. In a presentation phase, the subject was given an index card, on which the word pairs tested in the following block were printed. The subject memorized the items until she was certain that she knew which response word was combined with each prompt. This hardly ever took longer than two minutes. By the fifth test block, the subject had studied all items. Still, throughout the entire experiment, she was shown a list of the relevant word pairs prior to each block so that she was always informed about the upcoming items.

As soon as the subject indicated that she knew the word pairs, the experimenter started the test phase. A test trial had the following structure: first, the subject heard a high warning tone (1000 hz) and simultaneously saw two horizontal fixation bars marking the left and right margin of the field where the prompt would be displayed shortly afterwards. The bars appeared in the same locations in all trials, regardless of the length of the prompts. The tone and the fixation bars were displayed for 200 ms and were followed by a 600-ms-pause. Then the prompt was presented for 150 ms, and the subject reacted by saying the response word as fast as possible. The speech onset was detected by the voice key, and the reaction time, measured from prompt onset, was computed and written into the data file. The prompt was followed by a pause of 1050 ms. Then the next trial began. If the subject had failed to react within 1000 ms after prompt onset, the trial structure was slightly different. In this case, a low "punishment" tone (500 hz) was played for 200 ms, starting 1000 ms after the onset of the prompt. It was followed by pause of 200 ms. The subject had been instructed to avoid this tone by reacting quickly enough (see figure 5.1).

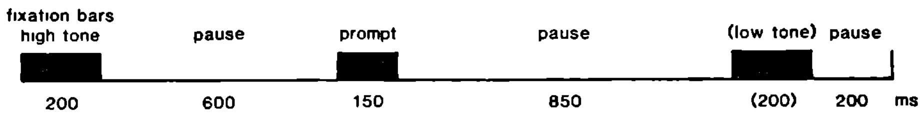


Figure 5.1: Structure of a test trial

The experimenter monitored the subject's responses and marked incorrect responses in the data file by pressing a key on her keyboard. A response was considered incorrect if the subject failed to respond, used a wrong response word, repaired the utterance ("kat- kano"), or included a filled pause in her response ("eh kamer"). These preliminary response codes were used to give performance feedback to the subject.

A scoring system had been developed to motivate the subject to respond as fast and as accurately as possible. At the end of each test block, a chart appeared on the monitor listing the mean reaction time and the number of correct, incorrect, and "slow" responses (that is, responses with latencies longer than 1000 ms), together with the corresponding scores. The subject earned one point for each correct response; she lost two points for each incorrect response and one point for each slow response and for each 100 ms mean reaction time. Thus, a subject who in a block of 25 trials made one error and reacted too slowly three times and whose mean reaction time amounted to 600 ms earned a total of 25-2-3-6=14 points. In order to keep track of her performance, the subject entered her scores into a form. In general, the subjects took the feedback quite seriously and seemed highly motivated.

5.3.6 Data analyses

The first step in the data analysis was to identify invalid data points on the basis of the taped performance record and to exclude them from further analyses. There were five classes of invalid data: 1. The subject did not respond at all to a prompt (missing response). 2. She selected an incorrect response word (wrong response). 3. She stuttered, repaired her utterance, or started with a filled pause or with a "mouth click", that is, with a clicking or smacking non-speech sound produced by the lips or the tongue (dysfluency). 4. The reaction time was longer than 1000 ms (slow response). 5. Finally, some data points were lost because the equipment did not function properly, the experimenter made an error, or the voice key was triggered by sounds other than the subject's speech (technical error). In addition, all latencies of less than 150 ms were classified as technical errors, even if the response sounded perfectly normal and there was no known technical problem in the respective trial. These data points are highly unlikely to be valid measurements of the speech onset latency.

The four categories of invalid data were derived upon inspection of the data from the first experiment. Since the predictions concerned the reaction times and not the errors, I will only occasionally refer to the error frequencies in the reports on the experiments. The distributions of the invalid data over the cells of the experiments are tabulated in appendix C.

Since there were 25 word pairs, each of which was tested five times in a homogeneous block and five times in a heterogeneous block, and since each block was repeated three times, a total of 750 data points was obtained from each subject. The valid reaction times for the five items of each set were combined to means per subject, test context, trial, and repetition. The resulting scores were analysed in an analysis of variance with the between-subjects factor "groups" and the within-subject factors "sets", "contexts", "trials", and "repetitions". For technical reasons, the homogeneity of the variance-covariance matrices could not be tested. Therefore, Geisser-Greenhouse conservative F tests were used (Kirk, 1968, p. 142 f. and p. 262). Only significant main effects and interactions are mentioned in the experimental reports. The complete tables of all results from the analyses of variance are listed in appendix B.

Clark (1973) has argued that in order to generalize from the results of a given psycholinguistic experiment to new samples of subjects and stimuli, one needs to regard both subjects and stimuli as levels of a random factor (see also Coleman, 1964). Accordingly, he proposes to run two analyses of variance, one with subjects and one with stimuli as a random factor, and to combine the resulting F-values (F_1 and F_2) for each factor to a new F-value (min F') which allows one to estimate the generality of the effect across different samples of subjects and stimuli (see also Winer, 1971). Min F' cannot exceed F_1 or F_2 whichever is smaller. In some cases F_1 might be significant, while F_2 and min F' are not significant (Forster & Dickinson, 1976).

Clark's proposal presupposes that the stimuli used in a given experiment represent a random selection from some population of stimuli which is the domain of generalization. In studies like the present there are questions about whether this condition is met (see Clark et al., 1976; Wike & Church, 1976). The items were carefully selected keeping a number of semantic and phonological criteria in mind.

Whether or not a given word pair was included in one of the sets depended not only on characteristics of those two words, but also on features of the other items in that set (see section 5.3.2). In some cases, *all* Dutch words which met the criteria for inclusion in a given set were used as test stimuli. It is unclear whether min F′ is appropriate under these conditions.

There are, of course, other ways of assessing the generality of experimental findings than using min F′-values, one such being the replication of experiments with new samples of subjects and stimuli. This route is taken in the present study. Many of the below experiments include replications of conditions from earlier experiments with new stimuli and subjects. For instance, whether a priming effect could be obtained from the first syllable of the response words was tested in experiments 1, 3, 5, and 6, using different sets of materials. The effect of primes consisting of the second syllable of the response words was investigated in experiments 2 and 4, and so on. As will become clear below, all major conclusions of the present research are based on the results of more than one experiment.

Notes

1. Alternatively, a picture naming task could have been used, or the subjects could have been asked to find words on the basis of definitions of their meanings (Bowles & Poon, 1985; Brown, 1979; Freedman & Landauer, 1966; Gruneberg & Monks, 1971; Loftus et al., 1974; Roediger et al., 1983). The paired-associate learning task has the advantage that any word (or nonword) can serve as a response, not only names of concepts which are easy to define or to represent graphically.

2. See appendix A for a translation of the stimulus materials.

3. Regardless of whether the speech rate is assumed to depend on the time-interval allowed for the encoding of each syllable, or on the level of activation which the segments must reach in order to be selected, more sound errors should arise in fast than in slow speech. In Dell's model, the segments of the current syllable have received less activation from the morpheme in fast than in slow speech and are therefore less likely to be the most highly activated segments at the moment of selection. Similarly, a low threshold, chosen in rapid speech, is quite likely to be reached by a competitor of a target segment before being reached by the target

itself. A high threshold, chosen in slow speech, will in most cases only be reached by the target segment, which becomes more and more strongly activated during the encoding cycle, while the activation of its competitors decays or at least increases more slowly.

4. The prediction that the implicit primes should have a facilitatory effect might seem implausible since in certain memory tasks, phonological relatedness between the targets has been shown to impair their recall (Thomassen, 1970). Phonological interference has, for instance, been reported in experiments using the immediate serial recall paradigm (ISR). In an ISR experiment, the subject is presented with a sequence of verbal stimuli, which she has to recall immediately after the end of the presentation in the correct order. Regardless of whether the stimuli were letters, whose names could be phonologically similar or dissimilar (Conrad, 1964; Conrad & Hull, 1964; Murray, 1968; Thomassen, 1970), or words (Baddeley, 1966a, 1968), lists of phonologically similar items turned out to be harder to recall than lists of phonologically dissimilar ones. For word stimuli, this phonological relatedness effect has been observed under visual as well as under auditory stimulus presentation (Baddeley, 1976; Baddeley & Lewis, 1981; Monsell, 1984). In an ISR experiment, the subjects apparently generate and retain representations of the phonological forms of the targets, and similarity between them leads to interference.

   The implicit priming paradigm differs from the ISR paradigm in several respects. First, the subjects can study the items as long as they wish before the test. Baddeley (1966b) and Baddeley and Dale (1966) provided evidence indicating that in such a situation the subjects are likely to recall the items on the basis of a semantic, rather than a phonological representation; hence, there is no basis for interference between phonologically similar items.

   Second, Wickelgren (1965) showed that the errors in the ISR paradigm stemmed mainly from the subjects' inability to recall the serial order of the retrieved items, whereas the retrieval of the individual items was facilitated slightly by their phonological relatedness (Baddeley & Lewis, 1981; Monsell, 1984; Thomassen, 1970). In the implicit priming paradigm, the subjects do not have to recall the order of the test items.

   Finally, the main dependent variable in the implicit priming paradigm is the utterance onset latency for the response words; in the ISR paradigm it is the percentage of correctly recalled items. How rapidly the items were retrieved in the ISR experiments is not known.

5. This only holds, if the subjects establish a working memory representation of the five relevant word pairs and selected the correct response word for each trial from this group of words, rather than searching their entire long-term memory store. In the latter case the implicit prime can function as an additional retrieval cue for the appropriate response word (Bower & Bolton, 1969; Gruneberg & Monks, 1971).

Evidence to support the assumption that the subjects generated working memory sets specific to each block and selected response words from these sets is provided by the selection errors. In practically all cases where a wrong response word was selected, that word was one of the response words used in the current test block. For example, in the first four experiments, wrong response words were selected in 159 trials (or 0.53% of all trials), and in 151 (or 95%) of these errors the incorrect response was one of the response words of the current test block. Five times, a subject read the prompt instead of naming the response word; in the remaining three errors, the response words stemmed from other test blocks of the experiment.

6. This chapter describes the stimulus materials and design of experiments 1 to 4 and of experiments 7 to 10. In the remaining experiments, six experimental sets of three word pairs each were used, together with a slightly different design, which will be described below.

6 The phonological encoding of successive syllables of a word

6.1 Overview

The first series of experiments tested the claim made by both Shattuck-Hufnagel (1979, 1983) and Dell (1986) that successive syllables of a word must be phonologically encoded one after the other, according to their order in the utterance. An alternative hypothesis is that they can be encoded in any order, so that the speaker can, for instance, first generate a representation of the *second* syllable and later append the first syllable "to its left" if that is convenient.

In experiment 1, disyllabic response words were implicitly primed by their first syllable, in experiment 2 by their second syllable. As was argued in section 5.2, the temporal order in which the syllables of a word are encoded should be reflected in the efficiency of these primes. If the syllables must be encoded sequentially, a priming effect should be observed in the first, but not in the second experiment.

Since all response words in the first two experiments were stressed on their first syllable, the word position and the stress value of the prime were confounded. In experiment 1, the primed syllable appeared word-initially and was stressed; in experiment 2, it appeared word-finally and was unstressed. In order to separate the effects of word position and stress value, experiments 3 and 4 were run, in which all response words were stressed on the *second* syllable. In experiment 3, they were again primed by their first syllable and in experiment 4 by their second syllable.

It was argued above (section 5.2) that the second syllable of the response words should not be an efficient implicit prime because the speaker cannot prepare for it *before* having encoded the preceding syllable. If this is true, a priming effect should be obtained from the second syllable of the response words, provided that the first syllable is also primed. The subject can then prepare for both the first *and* the second syllable. This hypothesis was tested in the last two experiments of this series. Trisyllabic response words were used, which were either primed by their first syllable alone or by their first and second syllable together. The disyllabic primes were expected to be more efficient than the monosyllabic ones.

6.2 Experiment 1

6.2.1 Stimuli

The stimuli of experiment 1 have already been extensively described above (section 5.2). The response words were disyllabic nouns, which began in a stressed CV-syllable. This syllable was the implicit prime.

6.2.2 Results

In experiment 1, the mean reaction time was shorter by 55 ms in the homogeneous than in the heterogeneous blocks, and the corresponding context effect was highly significant ($F(1;8)=34.938$, $MS_e=31869$, $p<.01$). The main effect of "sets" and the interaction of "sets" and "contexts" were also significant ($F(1;8)=23.617$, $MS_e=10001$, $p<.01$ and $F(1;8)=13.645$, $MS_e=4219$, $p<.01$ respectively; table 6.1.a). For all sets, the mean reaction time was shorter in the homogeneous than in the heterogeneous blocks, but this difference failed to reach significance in the /boe/-set (table 6.1.b). Significant effects were also obtained for "repetitions" ($F(1;8)=15.050$, $MS_e=17103$, $p<.01$; table 6.1.c) and for the interaction of "groups", "contexts", and "repetitions" ($F(1;8)=9.739$, $MS_e=6974$, $p<.05$; table 6.1.d). The mean reaction time was shorter in the homogeneous than in the heterogeneous blocks in all repetitions of both groups, but the priming effect was not significant in the first repetition of group 1 (table 6.1.e).

Table 6.1: Results of experiment 1

a) Mean reaction time (ms) per set and context and priming effect per set

	set					
	1	2	3	4	5	
context	/boe/	/ka/	/le/	/po/	/si/	mean
primed	630	548	542	606	573	580
unprimed	645	637	609	666	615	635
mean	637	592	576	636	594	607
priming effect	15	89	67	60	42	55

b) Analysis of simple effects: priming effect per set

set	MS	F(1;8)	p
1 /boe/	15851	1.626	ns
2 /ka/	583589	59.862	<.01
3 /le/	339959	34.871	<.01
4 /po/	268849	27.577	<.01
5 /si/	135490	13.898	<.01

MS_e=9749

c) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	610	571	559
unprimed	657	623	624
mean	633	597	591
priming effect	47	52	65

Table 6.1 (continued): Results of experiment 1

d) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	629	571	564	588	591	571	555	572
unprimed	640	626	634	633	673	620	613	635
mean	634	599	599	611	632	595	584	604
priming effect	11	55	70	45	82	49	58	63

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	7563	0,495	ns
rep 2	189063	12.380	<.01
rep 3	306250	20.053	<.01
group 2			
rep 1	430563	28.193	<.01
rep 2	150063	9.826	<.01
rep 3	203063	13.296	<.01
MS_e=15272			

6.2.3 Discussion

In interpreting the context effect, the significant interactions involving this factor must be taken into account. Consider first the interaction of "contexts" with "groups" and "repetitions" (tables 6.1.d and 6.1.e). In the first repetition, the priming effect was weak (11 ms) and failed to reach significance in group 1, whereas it was particularly pronounced (82 ms) and highly significant in group 2. This difference between the groups can be explained by reference to a practice effect. The two groups differed in the order in which the homogeneous and heterogeneous blocks were administered. In group 1, the homogeneous blocks preceded the heterogeneous ones in each of the three parts of the experiments; in group 2, the homogeneous blocks followed the heterogeneous ones. It seems reasonable to assume that the repetition of the items speeded the reactions because, for instance, less time was needed to read the prompts or, more likely, because the associations between the prompts and the response words had become more firmly established, and the response words could be selected more rapidly. This practice effect added up to the effect of the test contexts in group 2 and partially cancelled it in group 1. The order of administering the homogeneous and heterogeneous blocks noticeably affected the reaction times only in the first repetition. In the second repetition, the difference between the homogeneous and the heterogeneous blocks was about equally pronounced in both groups; and in the third repetition, it was slightly stronger in group 1 than in group 2.

The factor "contexts" also interacted with the factor "sets". As can be seen from tables 6.1.a and 6.1.b, the strength of the priming effect varied considerably across the sets. The priming effect was most pronounced in the /ka/- and /le/-set and least pronounced in the /boe/-set. There is no obvious phonological reason why the recurrent syllables in the five sets should vary in their efficiency as implicit primes. Since each word pair was tested in a homogeneous and in a heterogeneous block, the interaction cannot be explained by reference to characteristics of the individual word pairs either. Probably the selection of the response words was more difficult and time-consuming in some blocks than in others. In a block in which each prompt was only semantically related to its own and not to any other response word the selection should be easy. But if one or more prompts of a block were semantically related to more than one response word, the choice should be more difficult and time-consuming. The more difficult the lexical selection in a homogeneous block, the weaker was presumably the observed priming effect for the respective set. In the construction of the stimulus materials, an attempt had been made to find prompts which were semantically related to only one response word each. But the estimate of the semantic relatedness between the prompts and the response words was based on the intuitions of the experimenter and was not tested systematically. Therefore, it cannot be expected that the lexical selection was exactly equally difficult in all blocks.[1]

The analyses of the interactions involving the factor "contexts" revealed that the strength of this effect varied somewhat across the sets and across the combinations of "repetitions" and "groups", but in all cases the mean reaction time was shorter in the primed than in the unprimed condition. Thus, the results of experiment 1 clearly show that disyllabic response words could be implicitly primed by their first syllable, as had been predicted.

One possible interpretation of the priming effect is that the subjects prepared themselves for the utterance by rehearsing the recurrent string. Thereby its phonological segments became highly activated, the first syllable of the response words was encoded more rapidly, and the naming reaction began sooner than in the control condition. According to this account, the implicit primes facilitated the phonological encoding of the response words.

However, alternative interpretations of the priming effect are possible. First, since the implicit prime corresponded to the first syllable of the response words, the subjects could not only covertly rehearse the recurrent syllable between the trials, but could also bring their speech organs in an optimal starting position to utter the response words rather than keeping them in a neutral position. Such articulatory preparation could clearly be observed during the experiment. One could literally see the subjects make the respective movements between the trials. This raises the question of whether facilitation of phonological encoding contributed to the priming effect at all, or whether the effect was entirely due to articulatory preparation. At present, this issue cannot be decided. On the basis of other findings, I will later argue that the priming effect might in part be based on articulatory preparation, but cannot be exclusively due to it.

Second, one might argue that the subjects could not only prepare for the primed syllable on the phonological or/and articulatory level, but could actually utter it before selecting the appropriate response word. In principle, they could say the primed syllable immediately after the onset of the warning signal before even reading the prompt. In that case, the lexical selection of the response word would take place *after* the utterance onset. The response words would be produced in a way which has little in common with the way words are normally produced.

Fortunately, there is evidence which suggests that the subjects did *not* adopt this strategy. First, if they had done so, the reactions should have been much faster than they actually were. Using the same equipment as in the current study, Kraayeveld (1988) ran a slightly different experiment in which only one word was tested in each block. Instead of a prompt word, one of two strings ("xxx" or "000") was presented in each test trial. In response to the first string the subject said the response word as quickly as possible. No response was required when the other string was displayed. In this experiment, the subject could generate the phonological form of the response word in advance and only had to utter it as soon as the prompt appeared on the screen. If the subjects in the present experiment said the primed syllable immediately upon the presentation of the prompt and then selected the response word, the mean reaction time should have been about the same as in Kraayeveld's experiment. This was, however, not the case. Kraayeveld obtained mean latencies of 374 ms for monosyllabic and 365 ms for trisyllabic target words, whereas the mean reaction time in the homogeneous blocks of the current experiment amounted to 580 ms. This 200-ms-difference between the mean latencies suggests that the subjects in the current experiment engaged in certain planning processes before beginning the utterance which were not needed in Kraayeveld's experiment. Most likely, they read the prompt, selected a response word and generated its phonological representation.

A second piece of evidence against the supposition that the subjects uttered the primed syllable before selecting a response word is provided by the interaction of the factors "contexts" and "sets". It was argued above that the strength of the priming effect varied across the sets because the response words were more difficult to select in some sets than in others. If the lexical selection had taken place *after* the utterance onset, this interaction should not have been observed.

Finally, if the subjects performed some of the planning which is normally done prior to the utterance onset while they were already articulating the first syllable of the word, one might expect that they lengthened that syllable a bit in order to gain extra time for these planning processes. The length of the first syllable of the response words in the homogeneous and heterogeneous blocks was measured and compared, but no significant difference was found (means: 194 ms and 191 ms for the homogeneous and heterogeneous blocks; $F(1;8)=5.009$, $MS_e=365$).[2]

Thus, there is so far no evidence to support the supposition that the availability of the implicit primes induced a special strategy of word production, which could not be used in other situations. It can be assumed that the words were produced more or less as usual, except that their phonological encoding was facilitated or/and the subjects prepared themselves for the articulation by keeping their speech organs in an optimal starting position.

6.3 Experiment 2

6.3.1 Stimuli

The second experiment tested whether disyllabic nouns could be implicitly primed by their *second* syllable. Five experimental sets with five word pairs each were generated in which the response words had the second syllable in common (table 6.2). As in experiment 1, there were five homogeneous and five heterogeneous test blocks. In each of the homogeneous blocks, one complete set was tested. Each heterogeneous block induced one item from each set.[3]

Table 6.2: Prompt-response word pairs in experiment 2

1	/ding/	2	/ma/	3	/rie/
nieuws	melding	zaak	firma	zweet	porie
zee	branding	ziekte	reuma	roem	glorie
vertrek	scheiding	luipaard	poema	reeks	serie
eten	voeding	onderwerp	thema	onzin	larie
jurk	kleding	toneel	drama	steppe	prairie

4	/to/	5	/zel/
circus	salto	touw	vezel
besluit	veto	sneeuw	ijzel
camera	foto	steen	kiezel
bedrag	conto	vet	reuzel
wagen	auto	wesp	horzel

6.3.2 Results

In experiment 2, the mean reaction times in the homogeneous and in the heterogeneous test context were virtually identical (means: 635 ms vs. 632 ms; $F(1;8)<1$, $MS_e=4207$; table 6.3.a). In other words, no priming effect was obtained. Two interactions involving the factor "contexts" were significant, namely the interaction of "groups" and "contexts" ($F(1;8)=12.258$, $MS_e=4207$, $p<.01$) and the interaction of "groups", "contexts", and "repetitions" ($F(1;8)=11.706$, $MS_e=2770$, $p<.01$; table 6.1.c). The analysis of simple effects for the former interaction revealed that in group 1, the mean reaction time was significantly *longer* in the homogeneous than in the heterogeneous blocks. In group 2, on the other hand, the mean reaction time was *shorter* in the homogeneous than in the heterogeneous blocks, but this difference was not significant (table 6.1.d). The analysis of the two-way interaction showed that in both groups, the context effect was only significant in the first repetition, with the mean reaction time being shorter in the homogeneous blocks in group 1 and in the heterogenous blocks in group 2 (table 6.1.e).

In addition, significant main effects were obtained for "sets" ($F(1;8)=5.535$,

MS_e=4000, $p<.05$; table 6.3.a) and "repetitions" ($F(1;8)=28.219$, MS_e=10201, $p<.01$; table 6.3.b).

Table 6.3: Results of experiment 2

a) Mean reaction time (ms) per set and context
and priming effect per set

	set					
	1	2	3	4	5	
context	/ding/	/ma/	/rie/	/to/	/zel/	mean
primed	624	651	622	639	638	635
unprimed	629	639	625	632	634	632
mean	626	645	624	635	636	633
priming effect	5	-12	3	-7	-4	-3

b) Mean reaction time (ms) per repetition (rep) and context
and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	664	625	616
unprimed	658	619	618
mean	661	622	617
priming effect	-6	-6	2

c) Mean reaction time (ms) per group, repetition (rep), and context
and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	670	624	608	634	657	625	623	635
unprimed	636	608	614	620	680	630	623	644
mean	653	616	611	627	668	627	623	640
priming effect	-34	-16	6	-14	23	5	0	9

Table 6.3 (continued) Results of experiment 2

d) Analysis of simple effects priming effect per group

group	MS	F(1,8)	p
group 1	36750	8 735	< 05
group 2	15188	3 610	ns

MS_e=4207

e) Analysis of simple effects priming effects per group and repetition (rep)

condition	MS	F(1,8)	p
group 1			
rep 1	76563	23 565	< 05
rep 2	16000	4 925	ns
rep 3	3063	943	ns
group 2			
rep 1	33063	10 177	< 05
rep 2	1563	481	ns
rep 3	563	.173	ns

MS_e=3249

6.3.3 Discussion

In the discussion of experiment 1 (section 6 2 3), the reaction time differences between the homogeneous and the heterogeneous test blocks in the various combinations of groups and repetitions had been explained by reference to two factors: first, the implicit primes speeded the reactions in the homogeneous blocks relative to the heterogeneous ones, second, due to increased practice, the reactions were faster in those blocks which were tested second within each of the three parts of the experiment than in those which were tested first In experiment 2, only the latter effect was observed In both groups, the mean reaction time was shorter in those blocks which were tested in the second half of each part of the experiment. These were the heterogeneous blocks in group 1 and the homogeneous blocks in group 2. As in the first experiment, the order of testing the two types of blocks strongly affected the reaction times in the first repetition and then lost its impact.

Thus, the first two experiments yielded the expected pattern of results. A priming effect was obtained when the response words shared the first syllable, but not when they shared the second syllable.

6.4 Experiment 3

6.4.1 Introduction

Since all response words of experiments 1 and 2 were stressed on the initial syllable, the findings of these experiments *can* be described by reference to the word position of the prime, as was suggested above (section 6.3.3), but also by reference to its stress value. A priming effect was obtained when the response words shared the stressed syllable, but not when they shared the unstressed syllable.

In order to decide between these two descriptions, experiments 3 and 4 were run. In these experiments disyllabic response words were used which were stressed on the second syllable. In experiment 3 they were primed by their first syllable and in experiment 4 by their second syllable. If only the first, but not the second syllable of the response words is an efficient prime, a priming effect should be obtained in experiment 3, but not in experiment 4. Conversely, if only the stressed, but not the unstressed syllable is an efficient prime, a priming effect should be observed in experiment 4, but not in experiment 3.

6.4.2 Stimuli

The response words in experiment 3 were disyllabic nouns, in which the main stress fell on the second syllable. Since disyllabic monomorphemic nouns of Dutch tend to be stressed on their first syllable, the selection of the stimuli turned out to be difficult, and some rather infrequent words (such as "bouclé" and "kozak") had to be included. The response words within a set shared the initial CV-syllable.[4] The stimuli are listed in table 6.4.

Table 6.4: Prompt-response word pairs in experiment 3

1	/boe/	2	/de/	3	/ko/
winkel	boetiek	schouwburg	decor	ster	komeet
monnik	boeddhist	magazijn	depot	haas	konijn
kippen	boerin	professor	decaan	soldaat	kozak
tulpen	boeket	kenmerk	detail	rif	koraal
wol	bouclé	misdaad	delict	namaak	kopie

4	/ra/	5	/si/
afgrond	ravijn	boom	cipres
vliegtuig	raket	aanhaling	citaat
bericht	rapport	fruit	citroen
stamppot	ragout	medicijn	siroop
komkommer	radijs	rook	sigaar

6.4.3 Results

The mean reaction time was shorter by 43 ms in the homogeneous than in the heterogeneous blocks ($F(1;8)=51.805$, $MS_e=13342$, $p<.01$; table 6.5.a). The only significant interaction was the "groups"-by-"contexts" interaction ($F(1;8)=6.155$, $MS_e=13342$, $p<.05$; table 6.5.c). The priming effect was weaker in group 1 than in group 2, but it was significant in both groups (table 6.5.d). The interaction can be explained by reference to a practice effect which counteracted the priming effect in group 1 and added up to it in group 2 (see section 6.2.3).

The mean reaction time decreased significantly over the three repetitions of the test blocks ($F(1;8)=17.856$, $MS_e=13035$, $p<.01$; table 6.5.b) as well as over the trials within the blocks (means: 668 ms, 657 ms, 647 ms, 647 ms, and 642 ms for trials 1 to 5; $F(1;8)=7.410$, $MS_e=4166$, $p<.05$).

The priming effect in this experiment was numerically weaker than the effect obtained in experiment 1 (means: 43 ms and 55 ms), but the "experiments"-by-

"contexts" interaction in the joint analysis of variance of both experiments was not significant ($F(1;16)=1.108$, $MS_e=22606$).

Table 6.5: Results of experiment 3

a) Mean reaction time (ms) per set and context and priming effect per set

	set					
	1	2	3	4	5	
context	/boe/	/de/	/ko/	/ra/	/si/	mean
primed	623	659	617	637	619	631
unprimed	662	688	670	682	668	674
mean	642	674	644	660	644	653
priming effect	39	29	53	45	49	43

b) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	656	623	614
unprimed	698	666	659
mean	677	644	636
priming effect	42	43	45

c) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	667	635	634	645	646	612	594	617
unprimed	677	670	673	673	718	661	645	675
mean	672	652	653	659	682	636	620	646
priming effect	10	35	39	28	72	49	51	58

Table 6.5 (continued): Results of experiment 3

d) Analysis of simple effects: priming effect per group

group	MS	F(1;8)	p
group 1	148421	11.124	<.05
group 2	624891	46.836	<.01
MS_e=13342			

6.5 Experiment 4

6.5.1 Stimuli

Experiment 4 was comparable to experiment 2 in that in both experiments disyllabic response words were implicitly primed by their second syllable. The two experiments differed in the stress pattern of the response words. In the second experiment, the main stress fell on the first syllable; in the fourth experiment, it fell on the second syllable. The stimuli of experiment 4 are listed in table 6.6.

Table 6.6: Prompt-response word pairs of experiment 4

1	/ket/	2	/maat/	3	/niek/
kolen	briket	grootte	formaat	machine	techniek
snack	kroket	chemie	bromaat	angst	paniek
gerecht	parket	sla	tomaat	ziekte	kliniek
bom	raket	weer	klimaat	kleed	tuniek
tulpen	boeket	gorilla	primaat	verhaal	kroniek

4	/ces/	5	/tuur/
voortgang	proces	erfgoed	cultuur
uiterste	exces	riem	ceintuur
verlof	reces	glas	montuur
zwelling	abces	boek	lektuur
triomf	succes	aard	natuur

6.5.2 Results

The mean time was longer by 7 ms in the homogeneous than in the heterogeneous blocks ($F(1;8)=1.651$, $MS_e=12469$; table 6.7.a). The interaction of "groups" and "contexts" was significant ($F(1;8)=17.168$, $MS_e=12469$, $p<.01$) as was the interaction of "groups", "contexts", and "repetitions" ($F(1;8)=35.630$, $MS_e=3219$, $p<.01$; table 6.7.c). In the analysis of simple effects for the former interaction exactly the same pattern of results was obtained as in experiment 2. In group 1, the mean reaction time over all three repetitions was significantly *longer* in the homogeneous than in the heterogeneous blocks. In group 2, the mean reaction time was *shorter* in the homogeneous than in the heterogeneous blocks, but this difference was not significant (table 6.7.d). The analysis of simple effects for the latter interaction showed that in both groups the reaction time difference between the two types of blocks was only significant in the first repetition (table 6.7.e). As was discussed above, this pattern of results can be explained by reference to a practice effect (section 6.3.3).

In addition, the main effect of "repetitions" was significant ($F(1;8)=68.473$, $MS_e=7780$, $p<.01$; table 6.7.b) as was the main effect of "trials" (means: 691 ms, 682 ms, 671 ms, 666 ms, 661 ms for trials 1 to 5, $F(1;8)=19.409$, $MS_e=2250$, $p<.01$).

Table 6.7: Results of experiment 4

a) Mean reaction time (ms) per set and context
and priming effect per set

	set					
	1	2	3	4	5	
context	/ket/	/maat/	/niek/	/ces/	/tuur/	mean
primed	683	687	681	694	646	678
unprimed	673	682	679	678	641	671
mean	678	684	680	686	643	674
priming effect	-10	-5	-2	-16	-5	-7

Table 6.7 (continued): Results of experiment 4

b) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	719	669	647
unprimed	704	657	651
mean	711	663	649
priming effect	-15	-12	4

c) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	748	666	649	688	689	672	645	669
unprimed	675	652	642	656	733	661	661	685
means	712	659	645	672	711	667	653	677
priming effect	-73	-14	-7	-32	44	-11	16	16

d) Analysis of simple effects: priming effect per group

group	MS	F(1;8)	p
group 1	183715	14.734	<.01
group 2	50942	4.085	ns

MS_e=12469

Table 6.7 (continued): Results of experiment 4

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	336704	53.420	<.01
rep 2	11463	1.819	ns
rep 3	3035	.482	ns
group 2			
rep 1	117853	18.698	<.01
rep 2	6334	1.005	ns
rep 3	16183	2.568	ns
MS_e=6303			

6.5.3 Discussion

In experiments 1 and 3, the response words were primed by their *first* syllable, which was stressed in one experiment and unstressed in the other, and both times a significant priming effect was obtained. In experiments 2 and 4, on the other hand, the response words were primed by their *second* syllable, which was again either stressed or unstressed, and no priming effect was observed in either case. Thus, the efficiency of an implicit prime depends on its position in the response word and not on its stress value.

When the response words shared the first syllable, the subjects efficiently used the prime to prepare for the utterance on the phonological and maybe on the articulatory level. Such preparation was not possible when the response words had the second syllable in common. In this instance, one of two things could have happened: first, the recurrent string was rehearsed, which facilitated the phonological encoding of the second syllable, but simultaneously interfered with the encoding of the first syllable of the response word, and these two effects cancelled each other. Or, second, the implicit prime was simply ignored, presumably because its rehearsal would strongly interfere with the encoding of the first syllable, and help little, or not at all, in the encoding of the second syllable (see section 5.2).

So far, there is no evidence to decide between these possibilities. For the time being, I adopt the *second* account, mainly because it is more parsimonous to explain the absence of a priming effect by the assumption that the implicit prime did not have any effect than by postulating two processes whose effects cancelled each other. Furthermore, the mean reaction times in the homogeneous and heterogeneous blocks were nearly identical; they varied by 3 ms in experiment 2 and by 7 ms in experiment 4. If two processes were induced by the implicit primes, they must have been exactly equally strong, which, though possible, does not seem very likely. Finally, if the subjects had been rehearsing the second syllable before encoding the response word, many errors should have occurred in which the first syllable frame was filled by the segments of the second syllable. However, neither complete reversals of the two syllables of a response word (such as "ket-bri" instead of "briket"), nor anticipations of the second syllable (such as "ket- briket") were ever observed.

The difference in the efficiency of the two types of primes can be explained by reference to the temporal order in which the syllables must be encoded. At the beginning of the phonological encoding, the phonological segments of the first syllable must be highly activated in order to be selected as inserts for the first syllable frame. If they are rehearsed, they become preactivated and can be selected particularly rapidly; therefore, the utterance latency is reduced relative to the control condition without rehearsal. The segments of the second syllable, on the other hand, *must not* be highly activated when the phonological encoding begins; otherwise, they compete with those of the first syllable for the insertion into the first syllable frame. These segments must become highly activated a little later, when the second syllable frame is to be filled. In other words, the segments of successive syllables must be maximally activated and inserted into the syllable frame at different times, with the temporal order of their activation corresponding to their serial order in the word. The generation of the sound form of a word is a sequential process, which handles the syllables of the word one after the other, according to their order in the utterance. I will refer to this hypothesis as the "principle of sequential phonological encoding".

6.6 Experiment 5

6.6.1 Introduction

In the last section, it was argued that no priming effect was obtained from the second syllable of the response words because the speaker could not prepare efficiently for that syllable before encoding the preceding syllable. An implication of this account is that she should be able to prepare for the second syllable, if she can also prepare for the first syllable. This prediction was tested in experiment 5. Trisyllabic response words were used, which were either primed by their first syllable alone or by their first and second syllable together. The subjects were expected to rehearse the primes as in the previous experiments. The rehearsal of a disyllabic prime can be viewed as a recursive process, in which the first and second syllable alternately become the current node. Within each rehearsal cycle, first the phonological segments of the first syllable and then those of the second syllable become more highly activated than any other segments and are inserted into the slots of the syllable frame. Consequently, the segments of both syllables should become preactivated and should be inserted into the syllable frame particularly rapidly when the response word is encoded. Therefore, a stronger priming effect was predicted for the disyllabic primes than for the monosyllabic ones.

This finding would not only support the interpretation of the results of the previous experiments by reference to the principle of sequential phonological encoding, but would simultaneously rule out an alternative account, namely that the priming effects were exclusively due to articulatory preparation. It is unlikely that articulatory preparation can span more than the first syllable of the response words. If the disyllabic primes of experiment 5 turn out to be more efficient than the monosyllabic ones, the extra priming effect from the second syllable cannot be due to articulatory preparation, but must stem from facilitation of phonological encoding. Then the conclusion is warranted that the priming effect from the first syllable is also, at least in part, due to facilitation of phonological encoding rather than being merely an effect of articulatory preparation.

6.6.2 Stimuli

The response words of experiment 5 were trisyllabic nouns, which were stressed on the final syllable (table 6.8). One response word with four syllables, stressed prefinally, had to be included ("interesse"). Six sets with three word pairs each were generated. In three sets, the response words shared the first syllable (type 1 sets), in the remaining sets, they shared the first and second syllable (type 2 sets). The set size had to be reduced to three word pairs because it was not possible to find larger groups of trisyllabic nouns which shared the initial two syllables and had the same stress pattern.

Table 6.8: Prompt-response word pairs of experiment 5

type 1 sets

1	/ar/	2	/mi/	3	/pe/
bewijs	argument	fruit	mirabel	vogel	pelikaan
voorraad	arsenaal	omroep	microfoon	snoep	pepermunt
olijf	artisjok	gesteente	mineraal	leraar	pedagoog

type 2 sets

4	/inte/	5	/kolo/	6	/para/
brein	intellekt	soldaat	kolonel	hel	paradijs
algebra	integraal	pionier	kolonist	worm	parasiet
aandacht	interesse	kleur	koloriet	regen	paraplu

6.6.3 Design and data analysis

The experimental design was altered slightly relative to the earlier experiments. The factor "sets" now had six rather than five levels.[5] In order to obtain test blocks of about the same length as in the previous experiments with a reduced number of items, the number of trials per word pair and test block was increased from five to eight. Hence, the factor "trials" now had eight levels. The remaining design factors remained unchanged. This design was also employed in all later experiments in which two types of sets were tested.

Planned comparisons were used to test whether the priming effect was significant for each type of sets and whether it was more pronounced in the type 2 sets than in the type 1 sets (Kirk; 1968, p. 73 ff. and 267 f.). The reported significance levels are based on one-tailed tests.

6.6.4 Results

A significant priming effect of 23 ms was obtained ($F(1;8)=12.283$, $MS_e=32322$, $p<.01$; table 6.9.c). The "sets"-by-"contexts" interaction was also significant ($F(1;8)=9.943$, $MS_e=9067$, $p<.05$; table 6.9.b). In the sets of type 1 the mean priming effect amounted to 14 ms, in those of type 2 to 32 ms (table 6.9.a). Both effects were significant ($t=2.335$, $p<.05$ for the type 1 sets, and $t=5.421$, $p<.01$ for the type 2 sets) as was the difference in the strength of the effect between the two set types ($t=2.123$; $p<.05$). In addition, a significant effect of "repetitions" was obtained ($F(1;8)=40.043$, $MS_e=31070$, $p<.01$; table 6.9.c).

Table 6.9: Results of experiment 5

a) Mean reaction time (ms) per set, set type, and context
and priming effect per set and set type

	type 1 sets				type 2 sets			
	1	2	3		4	5	6	
context	/ar/	/mi/	/pe/	mean	/inte/	/kolo/	/para/	mean
primed	613	582	601	599	605	567	576	583
unprimed	606	613	621	613	599	631	616	615
mean	610	597	611	605	602	599	596	601
priming effect	-7	31	20	14	-6	64	40	32

b) Analysis of simple effects: priming effect per set

set	MS	F(1;8)	p
1 /ar/	6427	.497	ns
2 /mi/	114622	8.856	$<.05$
3 /pe/	47478	3.668	ns
4 /inte/	3809	.294	ns
5 /kolo/	492703	38.068	$<.01$
6 /para/	183251	14.159	$<.01$

MS_e=12943

c) Mean reaction time (ms) per repetition (rep) and context
and priming effect per repetition

context	rep 1	rep 2	rep 3	mean
primed	636	571	566	591
unprimed	652	604	588	614
mean	644	587	577	603
priming effect	16	33	22	23

6.6.5 Discussion

A significantly stronger priming effect was obtained when the response words shared the first *and* second syllable than when they shared only the first syllable, as had been predicted.

However, the priming effects in this experiment were relatively weak. In experiments 1 and 3, where disyllabic response words had been primed by their first syllable, effects of 55 ms and 43 ms had been obtained. In experiment 5, the mean priming effect over all sets amounted to only 23 ms, and a priming effect of 14 ms was obtained from the monosyllabic primes. Why the priming effects in the present experiment were so weak, is unclear. Smaller sets and longer response words were used than in the earlier experiments, and the frequency of the response words in spoken and written language was probably lower. These factors might, in some unknown way, have depressed the priming effects. In addition, the items of the /inte/-set had not been selected very well. Two semantically related word pairs, "brein-intellekt" and "aandacht-interesse", had been inadvertently included, which probably rendered the lexical selection in this set particularly difficult and cancelled the priming effect. No explanation can be offered for the absence of a significant priming effect in the /pe/- and /ar/-set.

Because of the weakness of the obtained effects, the experiment was repeated with new stimulus materials. The goal of the replication was to establish whether the most important result, the difference in the efficiency of monosyllabic and disyllabic primes, would be obtained again with new word pairs.

6.7 Experiment 6

6.7.1 Stimuli

It turned out to be impossible to find enough appropriate monomorphemic response words for experiment 6. Two sets had to be included in which the priming syllables were prefixes (/epi/ and /mono/). The results were analysed separately for these and the remaining sets. The /epi/-set included two response words with four syllables. The stimuli are listed in table 6.10.

Table 6.10: Prompt-response word pairs in experiment 6

		type 1 sets			
1	/ba/	2	/di/	3	/e/
kleinigheid	bagatel	consul	diplomaat	label	etiket
sabel	bajonet	onderwijs	didaktiek	toerist	emigrant
kerk	basiliek	orkest	dirigent	kracht	energie
		type 2 sets			
4	/epi/	5	/kara/	6	/mono/
nawoord	epiloog	vla	karamel	rots	monoliet
deel	episode	tocht	karavaan	paraaf	monogram
klier	epifyse	geweer	karabijn	toespraak	monoloog

6.7.2 Results

The mean reaction time was shorter by 55 ms in the homogeneous than in the heterogeneous blocks ($F(1;8)=30.202$, $MS_e=71536$, $p<.01$; table 6.11.c). The "sets"-effect was significant ($F(1;8)=8.694$, $MS_e=16113$, $p<.05$) as well as the interaction of "sets" and "contexts" ($F(1;8)=11.809$, $MS_e=12067$, $p<.01$; table 6.11.a). In all sets, the mean reaction time was shorter in the primed than in the unprimed condition, but this difference failed to reach significance in the /ba/- and in the /di/-set (table 6.11.b). The priming effect was significant for both types of sets ($t=3.456$, $p<.01$ for the type 1 sets and $t=10.623$, $p<.01$ for the type 2 sets), and it was stronger by 57 ms in the type 2 sets than in the type 1 sets ($t=5.068$, $p<.01$).

Particularly strong priming effects were obtained in those sets in which the implicit prime was a prefix, that is, in the /epi/- and in the /mono/-set. However, the difference in the strength of the mean priming effect for these two sets on the one hand and the /kara/-set on the other hand only reached on the 10-% -level of significance (means: 91 ms vs. 67 ms; $t=1.354$). The effect in the /kara/-set was significantly stronger than the mean effect in the three type 1 sets ($t=2.624$, p<.05). Thus, the disyllabic primes were more efficient than the monosyllabic ones, regardless of whether they represented prefixes or not.

The "groups"-effect was significant ($F(1;8)=18.280$, $MS_e=248931$, $p<.01$) as were the "groups"-by-"contexts" interaction ($F(1;8)=12.629$, $MS_e=71536$, $p<.01$) and the two-way interaction of "groups", "contexts", and "repetitions" ($F(1;8)=16.497$, $MS_e=7928$, $p<.01$; table 6.11.d). For some reason, the subjects in the first group reacted considerably more slowly than those in the second group. This difference was more pronounced in the homogeneous than in the heterogeneous blocks. The priming effect was much stronger in group 2 than in group 1 (91 ms vs. 20 ms); in fact, it was not significant in the first group at all (table 6.11.e). The analysis of simple effects for the two-way interaction showed that the priming effect was significant in all repetitions in group 2, but only in the second repetition in group 1 (table 6.11.f). In previous experiments, the priming effect had also been somewhat more pronounced in group 2 than in group 1 (see section 6.2.3). Why this difference was so pronounced in the present experiment is unclear. Finally, the main effect of "repetitions" was also significant ($F(1;8)=12.921$, $MS_e=57457$, $p<.01$; table 6.11.c).

Table 6.11: Results of experiment 6

a) Mean reaction time (ms) per set, set type, and context and priming effect per set and set type

	type 1 sets				type 2 sets			
	1	2	3		4	5	6	
context	/ba/	/di/	/e/	mean	/epi/	/kara/	/mono/	mean
primed	598	603	567	590	532	556	521	536
unprimed	614	623	611	616	611	623	624	619
mean	606	613	589	603	571	590	572	578
priming effect	16	20	44	26	79	67	103	83

Table 6.11 (continued): Results of experiment 6

b) Analysis of simple effects: priming effect per set

set	MS	F(1;8)	p
1 /ba/	30839	1.403	ns
2 /di/	46789	2.129	ns
3 /e/	230812	10.502	$<.05$
4 /epi/	744849	33.891	$<.01$
5 /kara/	535597	24.370	$<.01$
6 /mono/	1284154	58.429	$<.01$

MS_e=21978

c) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3	mean
primed	593	552	544	563
unprimed	650	613	591	618
mean	621	582	567	590
priming effect	57	61	47	55

d) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	660	605	597	620	526	499	491	505
unprimed	654	643	622	640	645	583	559	596
mean	657	624	610	630	586	541	525	551
priming effect	-6	38	25	20	119	84	68	91

e) Analysis of simple effects: priming effect per group

group	MS	F(1;8)	p
group 1	134876	1.885	ns
group 2	2929104	40.946	$<.01$

MS_e=71536

Table 6.11 (continued): Results of experiment 6

f) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	4023	.138	ns
rep 2	176680	6.065	<.05
rep 3	77957	2.676	ns
group 2			
rep 1	1697236	58.264	<.01
rep 2	847406	29.090	<.01
rep 3	549085	18.850	<.01
MS_e=29130			

6.8 Discussion

Experiment 6 yielded substantially stronger priming effects than the preceding experiment. The 83-ms-effect of the disyllabic primes might even seem "suspiciously" strong, and an interpretation already proposed in the discussion of experiment 1 (section 6.2.3) might be considered again, namely that the subjects first uttered the recurrent string and only later selected a response word. In that case, the production process investigated here would have little in common with the normal process of word production.

Above, two arguments were brought forward against this interpretation which also apply to the results of experiments 5 and 6. First, the observed reaction times seem much too long to result from such a strategy. In the experiment by Kraayeveld (1988) mentioned above, in which the subjects could generate the complete phonological representation of a target word in advance and only had to utter it as soon as a prompt was given, a mean latency of 365 ms was obtained for trisyllabic target words. In the fifth and sixth experiment of the current study, on the other hand, the mean reaction times in the homogeneous blocks with disyllabic primes amounted to 583 ms and 536 ms respectively. Thus, it seems quite unlikely that the subjects uttered the primed string immediately upon the presentation of the prompt, as Kraayeveld's subjects presumably did, and selected the response word only afterwards.

Furthermore, if the subjects postponed the selection of the response word and the phonological encoding of its unprimed part until after the utterance onset, they might say the primed string somewhat more slowly than in the control condition in order to gain extra time for these processes. For experiment 6, the length of the primed syllables in the homogeneous blocks was determined and compared to the length of the same syllables in the heterogeneous blocks.[6] The mean length of the first syllable of the response words in the type 1 sets turned out to be virtually identical in the two conditions (92 ms vs. 94 ms), and the first two syllables of the response words in the type 2 sets were uttered slightly *faster* in the homogeneous than in the heterogeneous blocks (mean length: 188 ms vs. 195 ms). Hence, there is no evidence to support the supposition that the implicit primes induced a production strategy which was specific to the utterance situation in the homogeneous blocks. Instead, the words can be taken to be produced in much the same way as in the heterogeneous blocks, except that the generation of their word forms was facilitated by the primes.

The most important result of experiments 5 and 6 is that disyllabic primes were more efficient than monosyllabic ones. This finding helps to determine the locus of the priming effects. The extra effect obtained from the second syllable of the response words cannot be due to articulatory preparation, but most likely stems from facilitation of the phonological encoding of the response words. If the phonological encoding of the second syllable of a response word is facilitated when this syllable is primed, the same can be expected for the first syllable. Hence, it is reasonable to assume that the priming effect obtained from the first syllable is also, at least in part, based on facilitation of phonological encoding.

Dell's (1986) model of phonological encoding predicts that a priming effect should be obtained when the response words share the first syllable, but not when they share the second syllable. These predictions were confirmed by the results of the first four experiments. What might at first sight seem puzzling from the perspective of this model are the results of experiments 5 and 6 where the second syllable of the response words turned out to be an efficient prime, provided that the first syllable was also primed. One might wonder why the preactivated phonological segments of the two primed syllables did not compete with each other, rendering the selection of the appropriate inserts for the syllable frames particularly difficult rather than facilitating it. Apparently, the primed segments were not merely preactivated, but the subjects must have generated and rehearsed a representation of the primed string, in which the order of the syllables was specified. One can think of this rehearsal as a recursive process, in which alternately the segments of the first and of the second syllable become more highly activated than any other segments and are inserted into the syllable frame.

Thus, the order of the syllables is defined by the temporal order in which they are encoded. It is possible to prepare for the second syllable of a word by inserting its segments into the slots of the syllable frame at a certain time, namely after having encoded the first syllable. But one cannot begin the phonological encoding of a word by selecting the segments of its second syllable and later add the segments of its first syllable.

Notes

1. The /boe/-set probably was a particularly difficult set. The priming effect was relatively weak, and the subjects made many more errors when the items of this set were tested together in a homogeneous block than when they were distributed over the five heterogeneous blocks. 93 errors were observed in the former condition as compared to 42 in the latter. In the remaining four sets, the error frequencies varied by only 2 to 6 between the two test contexts, and the mean error frequency per set and context was lower (31 and 30 respectively in the homogeneous and in the heterogeneous test context).

   A confusion matrix was set up for those trials in the homogeneous /boe/-block in which the subjects selected a wrong response word. Among the 26 responses in this category, 15 occurred in response to "roof", and the wrong answer in 13 of these cases was "boete". It is likely that the particular difficulty of the lexical selection in this set is at least in part due to the unfortunate inclusion of the semantically related pairs "straf-boete" (punishment-fine) and "roof-boeven" (robbery-scoundrel) in the stimulus materials.

2. The length of the first syllable was defined as the interval between the onsets of the word-initial consonant and the initial consonant of the second syllable. It was measured for 180 out of the 750 responses (or 24%) obtained from each subject. From each set, those three response words were selected for which the onset of the second consonant could be determined most easily ("boedel", "boeking", "boete", "kabel", "kamer", "kater", "lepel", "lepra", "lezing", "poker", "poten", "pose", and "sieraad", "citer" and "sisal"). The length of the first syllable of these words was determined for all valid responses in the last three trials of each block in the second and third part of the experiment. The selected words were digitized using a 10-kHz sampling rate and a 5-kHz low pass filter setting. Measurements were made using a waveform editing program. The measured values for the three selected responses per set were combined to means per subject, context, repetition, and trial and were subsequently analysed in a five-way analyses of variance with the factors "groups", "sets", "contexts", "repetitions", and "trials". Only the factor "sets" yielded a significant effect ($F(1;8)=47.071$, $p<.01$, $MS_e=2474$).

3. The complete stimulus materials of all experiments is listed in appendix A.

4. Inadvertently, one response word beginning in a CVC-syllable ("rapport") was included.

5. Alternatively, one can regard "set types" as a new design factor with two levels. In this case, the distinction between the three sets within a set type must be given up, and the analysis must be based on means combining the data from the three sets of a type. This analysis was carried out for all experiments in which two types of sets were tested, in addition to the main analysis which included the factor "sets"with six levels. The results of the two analyses were always comparable; that is, whenever the t-test following the main analysis showed that the priming effect was significantly stronger for one set type than for the other, the "set types"-by-"contexts" interaction in the additional analysis was also significant, and whenever the t-test was not significant, the interaction was not significant either. Therefore, only the results of the main analyses are reported here.

6. The length of the initial one or two syllables was measured for roughly 17% of the responses, namely for all valid responses in the last four trials of the second repetition of each block. The measurements were combined to means per subject, set, context, and trial and were analysed in a four-way analysis of variance with the

factors "groups", "sets", "contexts", and "trials". Only the factor "sets" yielded a significant effect ($F(1;8)=93.520$, $p<.01$, $MS_e=2526$).

7 The phonological encoding inside the syllable

7.1 Introduction

While the experiments described in the last chapter investigated the phonological encoding of successive syllables of a word, those reported in the current and in the following chapter concern the phonological encoding within a syllable. In this chapter, I only discuss the encoding of syllables in which each syllable constituent corresponds to one phonological segment. The encoding of syllables with constituents that comprise more than one segment is taken up in the next chapter.

In Dell's model, all segments of a syllable are activated and selected more or less at the same time. They are linearized by being associated to the ordered slots of the syllable frame. I will refer to this assumption as the "parallel encoding hypothesis". An alternative hypothesis is that the encoding of a syllable is a serial process, in which the segments are activated, selected, and associated to their positions one after the other, as they appear in the utterance. I will call this assumption the "sequential encoding hypothesis".

Both hypotheses seem plausible. In favour of Dell's proposal it can be argued that parallel processing is probably faster than sequential processing. The sequential encoding hypothesis, on the other hand, can be supported by the argument that a model in which the segments within a syllable and the syllables within a word are linearized in the same way, namely by being activated and selected in a certain order, is more parsimonious than a model in which the syllables and the segments within the syllables are ordered by different principles. Moreover, one might find it more economical to assume that the segments are activated and selected in the correct order in the first place than that they are first retrieved as an unordered set and are subsequently linearized.

Experiments 7 to 12 investigated which of these hypotheses, if any, is correct. In experiment 7, disyllabic response words, which began in a CV-syllable, were implicitly primed by the onset of that syllable (as in "*k*ade, *k*ever, *k*ilo"); in the next experiment, they were primed by the following vowel (as in "b*o*ter, k*o*ning, s*o*fa"). The question was, of course, whether these primes would affect the response latencies. The parallel and the sequential hypothesis make the same prediction for experiment 7, but differ in their predictions for experiment 8.

Consider the parallel encoding hypothesis first. When a syllable is encoded, the activation spreads in parallel from the syllable node to the segments, which, after a while, reach the selection threshold and are inserted into the slots of the syllable frame. Since there is some random variation in the activation levels of the segments at the beginning of the encoding and in the amount of the activation they receive, they reach the threshold at slightly different points in time. The encoding of a syllable is terminated as soon as the "slowest" segment is inserted into its slot.

The effect of an implicit prime consisting of one of the segments of a CV-syllable in a given trial depends on whether this segment is the "slow" segment or the "fast" one. If the primed segment happens to be the one which would otherwise have reached the selection threshold most slowly, the encoding cycle is terminated earlier than in the control condition, and the reaction is speeded.[1] If the primed segment is the one whose activation which would have reached the selection threshold first anyway, the "slow" segment must still be waited for; therefore, the duration of the encoding cycle remains unchanged, and the observed reaction time does not differ from the control condition. Provided that the segments do not differ systematically in the time they need to reach the threshold, a prime consisting of the consonant or the vowel of a CV-syllable should shorten the response latency in about 50% of the trials and leave it as it was in the remaining trials. Hence, the mean reaction time for a whole block of trials should be slightly shorter in the homogeneous than in the heterogeneous test condition.

Consider now how a syllable could be encoded under the sequential encoding hypothesis. I assume that the "current node" principle, which Dell proposes on the syllable level, also applies on the level of phonological segments. When a syllable is encoded, activation spreads in parallel from the syllable node to all of its segments. Initially, the first segment, being the current node, receives more activation from the syllable node than the remaining segments of the syllable. Therefore, it reaches the selection threshold first and is associated to the first slot of the syllable frame. Then, the second segment becomes the current node and is activated most strongly from the syllable node. It reaches the selection threshold next and is inserted into the second slot, and so on.

With respect to the priming effects expected from the first and second segment of a word, the sequential hypothesis makes analogical predictions as for the first and second syllable. If the first segment is primed, the subjects should rehearse it, it should become preactivated and reach the selection threshold particularly rapidly. Therefore, the reaction time should be shorter than in the control condition. Rehearsal of the second segment, on the other hand, should lead to massive interference in the selection of the first segment and to little or no facilitation of the selection of the second segment itself, for the reasons described above (see section 5.2). The best strategy the subjects could adopt probably is to ignore the fact that the response words have the second segment in common. Thus, the sequential encoding hypothesis predicts a priming effect from the first but not from the second segment of the response words.

A possible objection against the stimulus materials of experiments 7 and 8 is that a prime consisting of a single segment might be too short to have any noticeable effect on the phonological encoding of a disyllabic response word. To counter this argument, experiments 9 and 10 were run, in which monosyllabic response words were primed by their onset consonants and by their rhymes, respectively. In these experiments, a substantially higher proportion of the target segments was primed than in experiments 7 and 8. The predictions under the parallel and sequential encoding hypothesis are, of course, analogical to those for the preceding experiments. Under the parallel encoding hypothesis priming effects are expected in both experiments, whereas the sequential encoding hypothesis predicts a priming effect for experiment 9, but not for experiment 10.

In order to discriminate between the sequential and the parallel encoding hypothesis, it is crucial to establish that a priming effect obtained from a syllable onset is indeed, at least in part, due to facilitation of phonological encoding and not only to articulatory preparation. Effects of word-initial primes can obviously be due to either or both sources. Experiments 11 and 12 were analogical to experiments 5 and 6 and tested whether a priming effect could be obtained from the onset of the second syllable of the response words, given that the first syllable was also primed. In these experiments, articulatory preparation for the primed onset consonant was ruled out.

7.2 Experiment 7

7.2.1 Stimuli

For experiment 7, five sets of five word pairs each were generated. The response words were disyllabic nouns, beginning in a stressed CV-syllable. They were implicitly primed by the word-initial consonant (table 7.1).

Table 7.1: Prompt-response word pairs in experiment 7

1	/b/	2	/k/	3	/l/
stoffer	bezem	pond	kilo	onzin	larie
reis	boeking	insekt	kever	munt	lire
melk	boter	toren	koepel	ziekte	lepra
grondvlak	basis	prins	koning	kreng	loeder
kamp	bivak	rivier	kade	bloem	lotus
4	**/p/**	**5**	**/s/**	**practice set**	
stand	pose	honing	suiker	heer	dame
kerstmis	pasen	bank	sofa	spijker	hamer
slang	python	degen	sabel	docent	lezing
zout	pekel	cola	sinas	sigaar	tabak
luipaard	poema	reeks	serie	hond	poedel

7.2.2 Results

A significant context effect of 27 ms was obtained ($F(1;8)=95.713$, $MS_e=2979$, $p<.01$; table 7.2.a). The interactions of "contexts" and "groups" and of "contexts", "repetitions", and "groups" were also significant ($F(1;8)=38.459$, $MS_e=2979$, $p<.01$ and $F(1;8)=17.514$, $MS_e=1651$, $p<.01$ respectively; table 7.2.c). The analyses of simple effects showed that the priming effect was significant in each group (table 7.2.d) and in each repetition within each group with the exception of the first repetition in group 1 (table 7.2.e). This pattern of results again reflects the interaction of the effect of the two test contexts with the practice effect, which was discussed above (section 6.2.3).

Significant main effects were also obtained for the factors "repetitions" ($F(1;8)=83.308$, $MS_e=4499$, $p<.01$; table 7.2.b), "trials" (means: 631 ms, 623 ms, 616 ms, 617 ms, 610 ms for trials 1 to 5; $F(1;8)=11.241$, $MS_e=1724$, $p<.05$), and "sets" ($F(1;8)=10.255$, $MS_e=10672$, $p<.05$; table 7.2.a).

Table 7.2: Results of experiment 7

a) Mean reaction time (ms) per set and context and priming effect per set

	set					
	1	2	3	4	5	
context	/b/	/k/	/l/	/p/	/s/	mean
primed	628	605	598	625	571	606
unprimed	645	635	621	651	613	633
mean	636	620	610	638	592	619
priming effect	17	30	23	26	42	27

Table 7.2 (continued): Results of experiment 7

b) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	637	597	582
unprimed	662	626	611
mean	650	612	596
priming effect	25	29	29

c) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	686	640	619	649	588	555	544	562
unprimed	676	656	644	659	647	597	578	607
mean	681	648	631	654	618	576	561	585
priming effect	-10	16	25	10	59	42	34	45

d) Analysis of simple effects: priming effect per group

group	MS	F(1;8)	p
group 1	18750	6.294	$p<.05$
group 2	379688	127.455	$p<.01$

$MS_e=2979$

Table 7.2 (continued): Results of experiment 7

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	6233	2.977	ns
rep 2	15555	7.428	<.05
rep 3	37500	17.908	<.01
group 2			
rep 1	215436	102.883	<.01
rep 2	111995	53.484	<.01
rep 3	72731	34.733	<.01
MS_e=2094			

7.3 Experiment 8

7.3.1 Stimuli

Each experimental set of experiment 7 included one response word with /a/, /e/, /i/, /o/, and /oe/ as vowel of the first syllaɒle. For experiment 8, these items were recombined in such a way that the response words within a set shared the vowel of the first syllable rather than the onset consonant (table 7.3). Only one item of experiment 7 had to be replaced by a new one. Since no adequate response word starting in /soe/ had been found, the pair "honing-suiker" had been included in the /s/-set of experiment 7 and was replaced by "ruzie-woede" in the /oe/-set of experiment 8.

Table 7.3: Prompt-response word pairs in experiment 8

1	/a/	2	/e/	3	/i/
grondvlak	basis	stoffer	bezem	kamp	bivak
rivier	kade	insekt	kever	pond	kilo
onzin	larie	ziekte	lepra	munt	lire
kerstmis	pasen	zout	pekel	slang	python
degen	sabel	reeks	serie	cola	sinas

4	/o/	5	/oe/
melk	boter	reis	boeking
prins	koning	toren	koepel
bloem	lotus	kreng	loeder
stand	pose	luipaard	poema
bank	sofa	ruzie	woede

7.3.2 Results

In experiment 8, the mean reaction times in the homogeneous and in the heterogeneous blocks differed by only 2 ms (means: 620 ms vs. 622 ms; $F(1;8)<1$, $MS_e=4617$; table 7.4.a). Two interactions involving the factor "contexts" were significant, namely the "contexts"-by-"groups" interaction ($F(1;8)=15.097$, $MS_e=4617$, $p<.01$) and the two-way interaction of "groups", "contexts", and "repetitions" ($F(1;8)=18.291$, $MS_e=2400$, $p<.01$; table 7.4.c). In group 1, the mean reaction time was significantly shorter in the heterogeneous than in the homogeneous blocks, whereas the reverse was true in group 2 (table 7.4.d). In both groups, the context effect was only significant in the first repetition (table 7.4.e). Similar patterns of results were observed in experiments 2 and 4 and were explained by reference to a practice effect (sections 6.3.3 and 6.5.3).

Significant main effects were obtained for "repetitions" ($F(1;8)=67.250$, $MS_e=4565$, $p<.01$; table 7.4.b), "trials" (means: 628 ms, 624 ms, 620 ms, 617 ms, 613 ms for trials 1 to 5; $F(1;8)=7.845$, $MS_e=1224$, $p<.05$), and "sets" ($F(1;8)=5.776$, $MS_e=3931$, $p<.05$; table 7.4.a).

Table 7.4: Results of experiment 8

a) Mean reaction time (ms) per set and context and priming effect per set

	set					
	1	2	3	4	5	
context	/a/	/e/	/i/	/o/	/oe/	mean
primed	604	625	621	613	637	620
unprimed	620	619	624	614	630	622
mean	612	622	623	613	634	621
priming effect	16	-6	3	1	-7	2

b) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	645	613	602
unprimed	652	613	600
mean	648	613	601
priming effect	7	0	-2

c) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	660	616	599	625	630	611	604	615
unprimed	632	609	598	613	672	616	602	630
mean	646	613	599	619	651	613	603	622
priming effect	-28	-7	-1	-12	42	5	-2	15

d) Analysis of simple effects: priming effect per group

group	MS	F(1;8)	p
group 1	27000	5.847	<.05
group 2	42188	9.138	<.05

MS_e=4617

Table 7.4 (continued): Results of experiment 8

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	49000	15.610	<.01
rep 2	2250	.717	ns
rep 3	63	.020	ns
group 2			
rep 1	110250	35.122	<.01
rep 2	1563	.498	ns
rep 3	250	.080	ns
MS_e=3139			

7.3.3 Discussion

Experiments 7 and 8 showed that disyllabic response words could be implicitly primed by their word-initial consonant, but not by the following vowel. These results support the sequential encoding hypothesis, according to which the segments of a syllable must be activated and inserted into the slots of the syllable frame one after the other, as they appear in the syllable, rather than the parallel encoding hypothesis, according to which they are activated and inserted into the slots of the syllable frame in parallel.

But the findings are also open to an alternative interpretation. One might argue that the priming effect in experiment 7 was exclusively due to articulatory preparation and that no effect of *phonological* facilitation was obtained in either experiment. The absence of a phonological priming effect might be due to the weakness of the primes. Maybe, the effect of preactivating one segment of a disyllabic response word is simply too small to be captured in the current paradigm.

According to this explanation, a phonological priming effect might have been obtained from the onset of a word-initial syllable as well as from its rhyme, if the primed strings had been longer and/or had included larger proportions of the target segments. In that case, the parallel rather than the sequential encoding hypothesis would have been supported.

To test this proposal, experiments 9 and 10 were run using monosyllabic response words. In experiment 9, they were primed by their onsets, in experiment 10 by their rhymes. Experiment 9 was, as such, of little interest since a priming effect from the word-initial consonant of the response words had already been found in experiment 7, but it served as a baseline condition for the evaluation of the result of the following experiment. If only experiment 10 had been run and a negative result had been obtained, one might have argued that for some reason monosyllabic response words could not be implicitly primed at all. The primes of experiment 10 were at least as long as the primes which had been shown to be efficient in experiments 1 and 3. Moreover, the proportion of primed target segments was higher than in those experiments. If the rhyme primes again turn out to be inefficient, this cannot be explained any more by the assumption that they include too few segments to have a measurable effect.

7.4 Experiment 9

7.4.1 Stimuli

In experiment 9, monosyllabic response words were used, which were primed by their word-initial consonants or consonant clusters (table 7.5).

Table 7.5: Prompt response word pairs in experiment 9

1	/d/	2	/h/	3	/kl/
ballet	dans	tent	hut	rots	klip
schaal	dop	tovenaar	heks	verf	kleur
karakter	deugd	voet	hiel	schoen	klomp
schilder	doek	stapel	hoop	tapijt	kleed
beest	dier	vuur	haard	winkel	klant
4	**/p/**	**5**	**/st/**	**practice set**	
uiteinde	pool	orkaan	storm	adelaar	valk
kat	poes	dorp	stad	insekt	mier
ruiter	paard	wesp	steek	hart	bloed
duim	pink	mode	stijl	broek	jurk
inkt	pen	trottoir	stoep	zee	meer

7.4.2 Results

A significant priming effect of 34 ms was obtained ($F(1;8)=33.470$, $MS_e=12670$, $p<.01$). The main effect of "sets" was significant ($F(1;8)=11.205$, $MS_e=8882$, $p<.05$) as was the interaction of "contexts" and "sets" ($F(1;8)=8.258$, $MS_e=3411$, $p<.05$; table 7.6.a). For all sets, the mean reaction time was shorter in the homogeneous than in the heterogeneous test context, but the difference failed to reach significance in the /d/- and /h/-set (table 7.6.b).

The main effect of "repetitions" was significant ($F(1;8)=25.444$, $MS_e=15397$, $p<.01$; table 7.6.c) as was the interaction of "groups", "contexts", and "repetitions" ($F(1;8)=12.765$, $MS_e=3695$, $p<.01$; table 7.6.d). The priming effect was significant in all repetitions for both groups with the exception of the first repetition of group 1 (table 7.6.e), where it was, most likely, cancelled by the practice effect favouring the heterogeneous test context (see section 6.2.3).

Table 7.6: Results of experiment 9

a) Mean reaction time (ms) per set and context and priming effect per set

	set					
	1	2	3	4	5	
context	/d/	/h/	/kl/	/p/	/st/	mean
primed	622	629	631	621	571	615
unprimed	640	643	669	659	633	649
mean	631	636	650	640	602	632
priming effect	18	14	38	38	62	34

b) Analysis of simple effects: priming effect per set

set	MS	F(1;8)	p
1 /d/	23113	4.392	ns
2 /h/	13558	2.576	ns
3 /kl/	106778	20.289	<.01
4 /p/	104896	19.931	<.01
5 /st/	288384	54.795	<.01

MS_e=5263

c) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	649	605	590
unprimed	677	639	629
mean	663	622	610
priming effect	28	34	39

Table 7.6 (continued): Results of experiment 9

d) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	662	598	581	614	636	613	600	616
unprimed	658	632	621	637	697	645	638	660
mean	660	615	601	625	666	629	619	638
priming effect	-4	34	40	23	61	32	38	44

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	1175	.176	ns
rep 2	75347	11.268	< 05
rep 3	98774	14.771	<.01
group 2			
rep 1	232677	34.795	< 01
rep 2	64601	9.661	< 05
rep 3	92458	13.827	< 01
MS_e=6687			

7.5 Experiment 10

7.5.1 Stimuli

In experiment 10, monosyllabic response words were primed by their rhymes. The stimuli are listed in table 7.7.

Table 7.7: Prompt-response word pairs in experiment 10

1	/aard/	2	/ens/	3	/ol/
kachel	haard	bril	lens	trui	wol
ruiter	paard	douane	grens	spijs	stol
prent	kaart	maag	pens	gat	hol
herberg	waard	dier	mens	kegel	bol
snor	baard	verlangen	wens	aarde	mol

4	/oek/	5	/uif/
roman	boek	havik	duif
schilder	doek	bot	kluif
vis	snoek	trog	ruif
bocht	hoek	grendel	schuif
heks	vloek	kar	huif

7.5.2 Results

The mean reaction time was longer by 4 ms in the homogeneous than in the heterogeneous blocks. The main effect of the factor "contexts" was not significant ($F(1;8)=1.731$, $MS_e=4529$; table 7.8.a). There were two significant interactions involving this factor, namely the interaction of "contexts" and "groups" ($F(1;8)=12.202$, $MS_e=4529$, $p<.01$; table 7.8.d) and the interaction of "contexts" and "repetitions" ($F(1;8)=13.325$, $MS_e=1392$, $p<.01$; table 7.8.b). In group 1, the mean reaction time was shorter in the heterogeneous than in the homogeneous blocks, whereas the reverse was true in group 2. The difference between the test contexts was only significant for group 1 (table 7.8.e).

The analysis of simple effects for the interaction of "contexts" and "repetitions" showed that the context effect was only significant in the first repetition (table 7.8.c). In that repetition, the mean latency was shorter by 37 ms in the heterogeneous than in the homogeneous blocks in group 1, while the means were virtually identical in group 2 (table 7.8.d); hence the overall context effect favouring the heterogeneous blocks. In the second and third repetition, the difference between the two types of blocks was about equally pronounced in both groups, but in one group the mean reaction time was shorter in the homogeneous blocks, and in the other group it was shorter in the heterogeneous blocks. Therefore, no context effect was observed when the data of the two groups were combined (see section 6.2.3 for a discussion of this interaction).

Significant main effects were obtained for the factors "repetitions" ($F(1;8)=44.955$, $MS_e=7600$, $p<.01$; table 7.8.b), "trials" (means 630 ms, 630 ms, 622 ms, 617 ms, 615 ms for trials 1 to 5; $F(1;8)=6.036$, $MS_e=2428$, $p<.05$), and "sets" ($F(1;8)=15.907$, $p<.01$; table 7.8.a).

Table 7.8: Results of experiment 10

a) Mean reaction time (ms) per set and context and priming effect per set

	set					
	1	2	3	4	5	
context	/aard/	/ens/	/ol/	/oek/	/uif/	mean
primed	625	606	618	621	656	625
unprimed	618	604	608	629	644	621
mean	621	605	613	625	650	623
priming effect	-7	-2	-10	8	-12	-4

b) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3
primed	661	617	598
unprimed	642	619	601
mean	651	618	600
priming effect	-19	2	3

Table 7.8 (continued): Results of experiment 10

c) Analysis of simple effects: priming effect per repetition (rep)

repetition	MS	F(1;8)	p
rep 1	26034	10.679	<.05
rep 2	328	.135	ns
rep 3	597	.245	ns

MS_e=2438

d) Mean reaction time (ms) per group, repetition (rep), and context
and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	666	620	594	626	655	613	603	624
unprimed	629	608	591	610	654	629	611	631
mean	647	614	592	618	655	621	607	628
priming effect	-37	-12	-3	-16	-1	16	8	7

e) Analysis of simple effects: priming effect per group

group	MS	F(1;8)	p
group 1	52367	11.563	<.01
group 2	10736	2.371	ns

MS_e=4529

7.5.3 Discussion

In experiments 9 and 10, the results of the preceding two experiments were replicated. A significant priming effect was obtained when the response words were primed by their onset consonants, but no effect was observed when their rhymes served as implicit primes. In explaining the absence of a priming effect in experiment 8, one might have argued that the primes were simply too short to have any measurable effect. The result of experiment 10 cannot be explained in this way since all primes included at least two phonological segments, and primes of this length had been shown to be efficient in earlier experiments using longer response words.

The findings of experiments 7 to 10 can be explained by reference to the sequential encoding hypothesis. But before this account is accepted, it must be established that the priming effect from the onset consonants was indeed due to phonological facilitation, and not merely to articulatory preparation.

In experiments 11 and 12, disyllabic response words beginning in a CV-syllable were either primed by their initial syllable or by that syllable plus the onset of the following syllable. If a stronger priming effect is obtained from the latter than from the former type of primes, the additional effect of the primed word-internal syllable onset cannot be due to articulatory preparation, but can be located on the phonological level. Then the conclusion is warranted that the priming effect from the word-initial consonant is also, at least partially, due to facilitation of the phonological encoding of the response words.

7.6 Experiment 11

7.6.1 Stimuli

The stimulus materials of experiment 11 consisted of six homogeneous sets with three word pairs each. All response words began in a stressed CV-syllable. In three sets, the response words only shared the first syllable (type 1 sets); in the remaining sets, they also shared the onset of the following syllable (type 2 sets). The word pairs are listed in table 7.9.

Table 7.9: Prompt-response word pairs of experiment 11

		type 1 sets			
1	/da/	2	/ha/	3	/ki/
rozijn	dadel	spijker	hamer	pond	kilo
tijdstip	datum	vis	haring	steen	kiezel
val	daling	sneeuw	hagel	fruit	kiwi
		type 2 sets			
4	/hav/	5	/kol/	6	/pol/
rogge	haver	oven	kolen	spel	polo
schip	haven	punt	colon	contract	polis
valk	havik	sinas	cola	Rusland	Polen

7.6.2 Results

A strong priming effect was obtained. The mean reaction time was shorter by 76 ms in the homogeneous blocks than in the heterogeneous ones ($F(1;8)=69.364$, $MS_e=59805$; $p<.01$; table 7.10.c). The "sets"-effect was significant ($F(1;8)= 13.029$, $MS_e=11919$, $p<.01$) as was the interaction of "sets" and "contexts" ($F(1;8)= 11.208$, $MS_e=7321$, $p<.05$; table 7.10.a). A significant priming effect was obtained for each set (table 7.10.b) and for each type of set ($t=8.382$, $p<.01$ for the type 1 sets and $t=14.305$, $p<.01$ for the type 2 sets). The effect was significantly stronger in the sets of type 2 than in those of type 1 (mean priming effects: 96 ms vs. 57 ms; $t=4.164$; $p<.01$).

Significant main effects were obtained for "repetitions" ($F(1;8)=42.093$, $MS_e= 38826$, $p<.01$; table 7.10.c) and for "trials" (means: 567 ms, 543 ms, 533 ms, 541 ms, 536 ms, 530 ms, 536 ms, 537 ms for trials 1 to 8; $F(1;8)=8.630$, $MS_e=5513$, $p.<05$).

Table 7.10: Results of experiment 11

a) Mean reaction time (ms) per set and set type and priming effect per set and set type

	type 1 sets				type 2 sets			
	1	2	3		4	5	6	
context	/da/	/ha/	/ki/	mean	/hav/	/kol/	/pol/	mean
primed	500	516	527	514	451	511	508	490
unprimed	572	578	562	571	561	598	599	586
mean	536	547	544	542	506	553	553	538
priming effect	72	62	35	57	110	87	91	96

b) Analysis of simple effects: priming effect per set

set	MS	F(1;8)	p
1 /da/	627258	39.035	<.01
2 /ha/	465710	28.982	<.01
3 /ki/	139635	8.690	<.05
4 /hav/	1448148	90.121	<.01
5 /kol/	896832	55.811	<.01
6 /pol/	981050	61.052	<.01

$MS_e = 16069$

c) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3	mean
primed	556	491	460	502
unprimed	614	574	547	578
mean	585	533	503	540
priming effect	58	83	87	76

Table 7.10 (continued): Results of experiment 11

d) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	577	498	475	517	534	484	445	488
unprimed	602	576	554	577	625	572	539	579
mean	590	537	514	547	580	528	492	533
priming effect	25	78	79	60	91	88	94	91

7.7 Experiment 12

7.7.1 Stimuli

Experiment 12 was a replication of experiment 11 with new stimuli (table 7.11).[2] Again, disyllabic response words were either primed by their initial CV-syllable (type 1 sets) or by that syllable plus the following consonant (type 2 sets). While the response words of experiment 11 were stressed on the first syllable, those of experiment 12 were stressed on the second syllable.

Table 7.11: Prompt-response word pairs of experiment 12

type 1 sets

1	/boe/	2	/ko/	3	/to/
winkel	boetiek	rif	koraal	komkommer	tomaat
kippen	boerin	namaak	kopie	podium	toneel
tulpen	boeket	soldaat	kozak	geheel	totaal

type 2 sets

4	/bar/	5	/kom/	6	/tab/
schuur	barak	specerij	komijn	rijtje	tabel
hoed	baret	grap	komiek	verbod	taboe
graaf	baron	ster	komeet	sigaar	tabak

7.7.2 Results

The results of experiment 12 replicate those of the preceding experiment. A significant priming effect of 58 ms was obtained ($F(1;8)=55.896$, $MS_e=4268$, $p<.01$; table 7.12.c). The interaction of "contexts" and "sets" was also significant ($F(1;8)=8.297$, $MS_e=5297$, $p<.05$; table 7.12.a). The priming effect was significant for each set (table 7.12.b) and for each type of sets ($t=7.439$; $p<.01$ for the type 1 sets and $t=12.929$; $p<.01$ for the type 2 sets). It was stronger by 32 ms in the type 2 sets than in the type 1 sets ($t=3.882$; $p<.01$; table 7.12.a).

The main effect of "repetitions" was significant ($F(1;8)=202.225$, $MS_e=5994$, $p<.01$; table 7.12.c) as was the interaction of "groups" with "repetitions" and "contexts" ($F(1;8)=5.376$, $MS_e=17003$, $p<.05$; table 7.12.d). The priming effect was significant in all repetitions of both groups with the exception of the first repetition of group 1 (table 7.12.e; see section 6.2.3 for a discussion of this pattern of results).

Table 7.12: Results of experiment 12

a) Mean reaction time (ms) per set, set type, and context and priming effect per set and set type

	type 1 sets				type 2 sets			
	1	2	3		4	5	6	
context	/boe/	/ko/	/to/	mean	/bar/	/kom/	/tab/	mean
primed	615	610	602	609	572	595	591	586
unprimed	644	661	647	650	642	665	670	659
mean	630	635	624	630	607	630	630	622
priming effect	29	51	45	41	70	70	79	73

Table 7.12 (continued): Results of experiment 12

b) Analysis of simple effects: priming effect per set

set	MS	F(1;8)	p
1 /boe/	100920	8.794	<.05
2 /ka/	312120	27.198	<.01
3 /to/	243000	21.175	<.01
4 /bar/	588000	51.237	<.01
5 /kom/	588000	51.237	<.01
6 /tab/	639480	55.723	<.01

MS_e=11476

c) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3	mean
primed	639	587	566	597
unprimed	692	643	628	655
mean	666	615	597	626
priming effect	53	56	62	58

d) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	642	567	546	585	636	606	587	610
unprimed	666	624	617	635	719	663	640	674
mean	654	595	581	610	678	635	613	642
priming effect	24	57	71	50	83	57	53	64

Table 7.12 (continued): Results of experiment 12

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	69120	2.715	ns
rep 2	389880	15.315	<.01
rep 3	604920	23.762	<.01
group 2			
rep 1	826680	32.472	<.01
rep 2	389880	15.315	<.01
rep 3	337080	13.241	<.01
MS_e=25458			

7.8 Discussion

In experiments 11 and 12, stronger priming effects were obtained when the response words shared the initial CV-syllable plus the following consonant than when they shared only the initial syllable. While the priming effects obtained from the word-initial consonants in experiments 7 and 9 could have been due to articulatory preparation or to phonological facilitation, the effects from the word-internal consonants in experiments 11 and 12 could not have an articulatory basis, but, most likely, stemmed from facilitation of phonological encoding. On the basis of this finding it can be argued that the priming effects from the word-initial consonants were also, at least in part, due to phonological facilitation. In fact, the effects of the word-initial and the word-internal primes were about equally strong. In experiments 7 and 9, where word-initial consonants served as primes, mean priming effects of 27 ms and 34 ms were obtained, whereas in experiments 11 and 12 extra priming effects of 39 ms and 32 ms were observed when the word-internal syllable onsets were primed in addition to the first syllable of the response words. This suggests that articulatory preparation did not play a major role in determining the strength of the priming effect.

In the second series of experiments, the phonological encoding of the response words was facilitated when they shared the word onset consonants, but not when they shared the rhyme of the first syllable. Dell's (1986) model of phonological encoding does not predict this pattern of results. Since the phonological segments of a syllable are assumed to be activated and inserted into the slots of the syllable frame in parallel, priming effects of about equal strength are expected from all segments of a syllable.

But this prediction presupposes that the phonological segments of a syllable do not vary systematically in how much time they need to reach the selection threshold (see section 7.1). The obtained results can be explained within the framework of Dell's model if it is instead assumed that the onset segment reaches the selection threshold *later* than the remaining segments of the syllable. Since the duration of the encoding cycle for a syllable is determined by its "slowest" segment, it will be shortened when the onset is primed. If one of the other segments is primed, it might reach the selection threshold faster than normally, but this does not affect the length of the encoding cycle and the observed reaction time, because the cycle is only terminated when the "slow" onset segment has reached the threshold. According to this explanation, the onset position is normally filled *after* the nucleus and coda positions, but this order is reversed, when the onset segment is primed.

I do not find this account very convincing, though. The claim that the first position of the syllable should be filled last is quite implausible, and Dell's theory does not provide any reason why onset segments should be particularly slow to activate. In general, a segment reaches the selection threshold later than other segments which are activated at the same time if its resting level of activation is lower or/and if it receives less activation from the superordinate node than the remaining segments. There is no reason why either of these conditions should be given for onset consonants. On the contrary, the claim that the onset should reach the selection threshold *before* the nucleus and coda segments would be easier to defend since in Dell's model the onset node is directly linked to the syllable node, whereas the nucleus and coda node are only indirectly linked to it via the rhyme node.

It is probably more adequate to modify Dell's proposal somewhat more radically, namely by giving up the parallel encoding hypothesis in favour of the sequential encoding hypothesis, according to which the segments within a syllable are selected serially, as they appear in the utterance. This hypothesis predicts a priming effect from the word onset, but no effect from the rhyme of the first syllable of the response words; and this is exactly the pattern of results obtained in experiments 7 to 10.

The sequential hypothesis further predicts a priming effect from a word-internal segment, provided that the preceding segments are also primed. In this case, the primed string of segments can be rehearsed, so that all of its segments become preactivated and reach the selection threshold particularly rapidly. This rehearsal can be viewed as a recursive process in which the primed segments are activated and selected over and over again, in their correct order. In each encoding cycle, the first segment is initially activated most strongly and reaches the selection threshold first, then the second segment is most strongly activated and is selected, and so on (see section 6.8).

This prediction was also confirmed. In experiments 1 and 7, disyllabic response words beginning in a stressed CV-syllable were primed by their first syllable and by the onset of that syllable respectively. The priming effect was significantly stronger in the former than in the latter experiment (mean priming effects: 55 ms vs. 27 ms; $F(1;16)=7.7965$, $MS_e=17424$, $p<.01$). Thus, the vowel of the first syllable, which, as experiment 8 showed, alone was not an efficient prime, contributed to the effect when the preceding segment was also primed. Similarly, in experiments 11 and 12, an additional priming effect was obtained from the onset of the second syllable of the response words, provided that the preceding syllable was also primed. On the other hand, no priming effect was found in experiments 2 and 4 when the second syllable of the response words alone was primed.

The pattern of results obtained in the present series of experiments closely resembles that of the first series. In both cases, only those primes were efficient which included the beginning of the response words, and the efficiency of these primes increased with their length. The findings suggest that the principle of sequential phonological encoding holds both between and within syllables. Apparently, the generation of the phonological representation of a word is a sequential process, which comprises a number of processing steps, each devoted to the selection of one phonological segment (or clusters of segments; see chapter 8). Since the temporal order in which the segments are selected determines their serial positions in the phonological representation, it is not possible to select the second segment of a word before the first one. The segment which is selected first will represent the beginning of the word. Later, new segments can be selected and appended "to its right", but not "to its left".

Notes

1. When one segment of the word-initial CV-syllable of a response word, say the onset consonant, is primed, activation spreads from the primed segment to all syllables which include that segment, and from there down again to the remaining segments of these syllables. Therefore, the nodes representing the first syllable and the first vowel of the response word are also indirectly activated. But simultaneously, competing syllables and vowels are also receiving some activation, so that the net effect of the spread of activation from the primed segment is hard to predict. I will leave this effect out of consideration here.

2. For practical reasons, experiment 12 took place immediately after the completion of experiment 11. Had I been able to analyse the data of experiment 11 first, experiment 12 would probably not have been run.

8 The phonological encoding of complex syllable constituents

8.1 Introduction

In Dell's (1986) model of phonological encoding, the phonological segments of a syllable are activated and selected in parallel and are ordered by association to the slots of the syllable frame. But the results of the experiments reported in the last chapter suggest that the segments of a syllable are selected sequentially, as they appear in the utterance, rather than in parallel. On the basis of these findings, one could argue that the notion of a syllable frame, to which the phonological segments are associated, could be given up. If the segments are linearized by being selected in a certain order, no additional ordering device is necessary and the syllable frame seems superfluous.

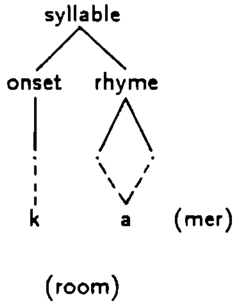
However, according to this proposal, the phonological representation of a word is nothing but an ordered set of phonological segments; its syllabic structure is not represented at all. From a linguistic viewpoint this is an unsatisfactory conclusion. In nonlinear phonology, word forms are viewed as multi-layered objects which comprise several tiers describing different aspects of the phonological representation. The melody of a word, that is, its representation as a string of phonological segments, is *one* tier; its syllabic structure is another tier of equal importance (chapter 2).

Against this background, it seems inadequate to eliminate the notion of the syllable from a theory of phonological encoding, just because it is not necessary to linearize the phonological segments. Instead, its function should be reconsidered. Rather than as a device playing a role in the generation of the melody of a word, the syllable can be regarded as a unit of an independent level of representation, the syllabic structure. The association between phonological segments and positions of the syllabic structure can be viewed as the integration of two complete and fully ordered representations capturing different aspects of the word form. By virtue of this mapping process each phonological segment is assigned to a position of the syllabic structure, and each position of the syllabic structure is filled by a segment.

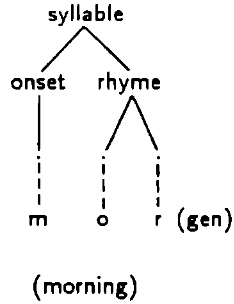
Under this perspective, yet another modification of Dell's model suggests itself. Dell assumes only one syllable frame with the slots onset, nucleus, and coda. Nothing is said about the specification of these slots, except that they are labelled and that they can be filled by single phonological segments, clusters, or "zero-elements". Within Dell's model, this is a sufficient characterization of the syllable because it only serves as a frame of reference for the linearization of the phonological segments and clusters. But since differences between syllables are not captured at all, it is not an adequate basis for the description of the syllabic structure of a word. Therefore, I do not follow Dell here, but assume a family of syllable templates, as was suggested in chapter 2. The syllables of a given language may differ in their linear structure, that is, in the number of terminal positions and the constraints on the phonological segments that can be linked to them, as well as in their hierarchical structure, that is, in the way the terminal positions are grouped to higher-order syllable constituents. In Dutch and English, for instance, there are syllables which include an onset and others which don't; the onset may embrace one or two positions, and so on.

If phonological encoding is viewed as a mapping process between the terminal positions of the syllabic structure and phonological segments, the question arises of how those syllable constituents are encoded which include more than one position. Consider as an example the encoding of the rhyme of a Dutch word-internal syllable with a full vowel. According to van der Hulst (1984), it comprises two obligatory positions, which can either be taken by a long vowel or by a short vowel plus a consonant (examples (8-1) and (8-2)).

(8-1)



(8-2)



With respect to the temporal order of the phonological encoding, three hypotheses suggest themselves. According to the first, called the "segment hypothesis" hereafter, the segments of a word are selected one after the other, irrespective of how they map onto the syllable constituents. The long vowel of "kamer" and the short vowel of "morgen" are both selected in one encoding cycle, and the following consonant is selected in the next cycle. According to the second hypothesis, "the position hypothesis", each encoding cycle is dedicated to one terminal position of the syllable. On this account, the short vowel of "morgen" is selected and associated to its position in one cycle, but it takes two cycles to select the long vowel of "kamer" and to associate it to its two positions. Finally, under the "constituent hypothesis", those phonological segments which map onto one syllable constituent are selected simultaneously, whereas those of different constituents are selected sequentially. Thus, the long vowel of "kamer" and the VC-group of "morgen" are both encoded in a single cycle. All three hypotheses are compatible with the assumption that the encoding of a CV- or CVC-syllable involves a series of encoding cycles. Under the "segment hypothesis" each cycle is devoted to one segment, under the "position hypothesis" to one terminal position of the syllable, and under the "constituent hypothesis" to one syllable constituent.

Evidence suggesting that the "constituent hypothesis" might be correct is provided by the coherence of syllable constituents in sound errors (section 3.2). Speech errors obviously reveal nothing about the temporal order in which the phonological segments are selected, but it seems at least a plausible hypothesis that those strings which behave as coherent units in errors are generated in a single encoding cycle.

Experiments 13 and 14 were run in order to decide between the "segment hypothesis" on the one hand, and the "position" and "constituent hypothesis" on the other. In experiments 1, 7, and 11, response words beginning in a CV-syllable, (CV-response words hereafter) were primed by their initial consonant, by their initial CV-group, and by their initial CVC-group (C-, CV-, and CVC-primes). The strength of the priming effect increased significantly from each of these primes to the next. In experiments 13 and 14, disyllabic response words beginning in a CVC-syllable (CVC-reponse words hereafter) were primed by the same types of strings, that is, by their initial consonant or their initial CV- or CVC-group.

Under the "segment hypothesis", each segment is encoded in a separate encoding cycle. Therefore, the strength of the priming effect should depend exclusively on the number of primed segments, and the same pattern of results should be obtained as in the experiments in which CV-response words were used.

Under the "constituent hypothesis", each encoding cycle is devoted to one syllable constituent. A CV-prime maps onto two complete constituents of a CV-response word, but only onto one complete constituent and part of the next constituent of a CVC-response word. Since in the latter case, the encoding cycle of the rhyme is only terminated when the unprimed postvocalic consonant has been selected, the effect of the prime should be weaker than in the former case. Similarly, since a CVC-prime comprises three constituents of a CV-response word (the onset and the rhyme of the first syllable and the onset of the second syllable), but only two constituents of a CVC-response word, it should also prime a CV-response word more efficiently than a CVC-response word. Finally, a CV-response word should be primed as efficiently by its initial CV-group as a CVC-response word by its initial CVC-group because in both cases the prime comprises two syllable constituents.

The "position hypothesis" makes the same predictions. The long vowel of a CV-syllable maps onto two terminal positions of the first syllable, while the short vowel of a CVC-syllable is only linked to one position. Therefore, a CV-response word should be primed more efficiently by its first two phonological segments than a CVC-response word. The same holds for primes including the first three segments of the response words. Furthermore, CV-primes should be as efficient for CV-response words as CVC-primes for CVC-response words because in both cases the primes include three positions. I will later discuss evidence which discriminates between the "constituent hypothesis" and the "position hypothesis".

In experiment 13, CVC-response words were primed by their onset consonant or by their initial CV-group. The first of these conditions is comparable to experiment 7, where CV-response words were primed by their initial consonant; the second is comparable to experiment 1 and to one condition of experiment 11, in which CV-response words were primed by their initial CV-syllable. In experiment 14, CVC-response words were primed by their initial CV-group or by the initial CVC-group. The results of this experiment can be compared to those of experiment 11, where CV-response words were primed by the same type of primes.[1]

8.2 Experiment 13

8.2.1 Stimuli

The response words of experiment 13 were disyllabic nouns, which began in a stressed CVC-syllable. In the sets of type 1, they shared the word-initial consonant, in those of type 2, they shared the initial CV-group (table 8.1).

Table 8.1: Prompt-response word pairs of experiment 13

		type 1 sets			
1	/p/	2	/s/	3	/t/
dijk	polder	religie	sekte	snelheid	tempo
nootje	pinda	laan	singel	atleet	turner
tijger	panter	emir	sultan	rogge	tarwe
		type 2 sets			
4	/de/	5	/ka/	6	/sa/
pan	deksel	universiteit	campus	ketjap	sambal
rivier	delta	pastoor	kansel	straf	sanctie
filosoof	denker	woestijn	cactus	geld	saldo

8.2.2 Results

In experiment 13, the mean reaction time was significantly shorter in the homogeneous than in the heterogeneous blocks ($F(1;8)=20.021$, $MS_e=23340$, $p<.01$). The mean priming effect for the type 1 sets, in which the response words shared only the initial consonant, amounted to 28 ms, in the type 2 sets, where the response words shared the initial CV-group, it was slightly *weaker*, namely 23 ms (table 8.2.a). The context effect was significant in both types of sets ($t=5.343$, $p<.01$ for the type 1 sets and $t=4.197$, $p<.01$ for the type 2 sets). The difference in the strength of the effect between the two set types did not reach the 10-% -level of significance, using a two-tailed test ($t=.766$).

The interaction of "groups" and "contexts" was significant ($F(1;8)=5.979$, $MS_e=23340$, $p<.05$; table 8.2.c). In both groups, the mean reaction time was shorter in the homogeneous than in the heterogeneous blocks, but the difference was only significant in group 2 (table 8.2.d). The interaction of "groups", "repetitions", and "contexts" was also significant ($F(1;8)=5.484$, $MS_e=13332$, $p<.05$; table 8.2.c). The mean reaction time was shorter in the primed than in the unprimed context in all repetitions for both groups with the exception of the first repetition of group 1, but the difference was only significant in the first and second repetition of group 2 (table 8.2.e). This pattern of results can be explained by assuming a practice effect which partially cancelled the priming effect in group 1 and added up to it in group 2 and which was particularly pronounced in the first part of the experiment (see section 6.2.3). Furthermore, a significant "sets"-effect ($F(1;8)=10.006$, $MS_e=13258$, $p<.05$; table 8.2.a) and a significant "repetitions"-effect ($F(1;8)=35.632$, $MS_e=21624$, $p<.01$; table 8.2.b) were obtained.

Table 8.2: Results of experiment 13

a) Mean reaction time (ms) per set, set type, and context and priming effect per set and set type

	type 1 sets				type 2 sets			
		1	2	3	4	5	6	
context	/p/	/s/	/t/	mean	/de/	/ka/	/sa/	mean
primed	583	580	578	581	551	589	546	562
unprimed	610	625	591	609	576	596	582	585
mean	597	602	585	595	564	593	564	574
priming effect	27	45	13	28	25	7	36	23

b) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3	mean
primed	603	564	547	571
unprimed	627	594	570	597
mean	615	579	559	584
priming effect	24	30	23	26

Table 8.2 (continued): Results of experiment 13

c) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	615	575	547	579	590	553	549	564
unprimed	606	596	569	590	647	592	571	603
mean	611	586	558	585	619	573	560	584
priming effect	-9	21	22	11	57	39	22	39

d) Analysis of simple effects: priming effect per group

group	MS	F(1;8)	p
group 1	48050	2.059	ns
group 2	558793	23.942	<.01
MS_e=23340			

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	10773	.646	ns
rep 2	52382	3.143	ns
rep 3	64823	3.889	ns
group 2			
rep 1	391674	23.499	<.01
rep 2	181865	10.911	<.05
rep 3	58774	3.526	ns
MS_e=16668			

8.3 Experiment 14

8.3.1 Stimuli

In experiment 14, disyllabic response words, beginning in a stressed CVC-syllable, were either primed by their word-initial CV-group (type 1 sets) or by their entire first syllable (type 2 sets). The stimuli are listed in table 8.3.

Table 8.3: Prompt-response word pairs in experiment 14

			type 1 sets		
1	/de/	2	/ka/	3	/sa/
pan	deksel	universiteit	campus	ketjap	sambal
rivier	delta	pastoor	kansel	straf	sanctie
filosoof	denker	woestijn	cactus	geld	saldo
			type 2 sets		
4	/hal/	5	/ker/	6	/mor/
station	halte	kruid	kervel	avond	morgen
gewicht	halter	feest	kermis	kreng	mormel
dammen	halma	gevangenis	kerker	specie	mortel

8.3.2 Results

The experiment yielded a significant priming effect of 47 ms ($F(1;8)=34.013$, $MS_e=45703$, $p<.01$; table 8.4.a). The priming effect was significant for both types of sets, amounting to 34 ms in the type 1 sets ($t=5.253$, $p<.01$) and to 59 ms in the type 2 sets ($t=9.807$, $p<.01$). The 25-ms-difference in the strength of the effect between the two types of sets was also significant ($t=2.719$, $p<.01$).

Significant main effects were obtained for "sets" ($F(1;8)=7.550$, $MS_e=16663$, $p<.05$; table 8.4.a) and "repetitions" ($F(1;8)=56.838$, $MS_e=26167$, $p<.01$; table 8.4.b). The interaction of "groups" and "repetitions" was also significant ($F(1;8)=8.333$, $MS_e=26167$, $p<.05$; table 8.4.c). The mean reaction time decreased over the repetitions in both groups, but the repetition effect was more pronounced in group 1 than in group 2. Furthermore, the interaction of "contexts" and "repetitions" was significant ($F(1;8)=7.667$, $MS_e=7915$, $p<.05$; table 8.4.b), which reflects the fact that the strength of the priming effect increased over the repetitions. The analysis of simple effects showed that it was significant in each repetition (table 8.4.c). Finally, the two-way interaction of "groups", "repetitions", and "contexts" was also significant ($F(1;8)=16.467$, $MS_e=7915$, $p<.01$;

table 8.4.d). The priming effect was significant in all repetitions for both groups except for the first repetition in group 1 (table 8.4.e; see section 6.2.3 for a discussion of this pattern of results).

Table 8.4: Results of experiment 14

a) Mean reaction time (ms) per set, set type, and context and priming effect per set and set type

	type 1 sets				type 2 sets			
	1	2	3		4	5	6	
context	/de/	/ka/	/sa/	mean	/hal/	/ker/	/mor/	mean
primed	563	611	605	593	559	563	585	569
unprimed	604	638	639	627	637	626	621	628
mean	583	625	622	610	598	594	603	599
priming effect	41	27	34	34	78	63	36	59

b) Mean reaction time (ms) per repetition (rep) and context and priming effect per repetition

context	rep 1	rep 2	rep 3	mean
primed	633	569	542	581
unprimed	664	613	605	628
mean	649	591	573	604
priming effect	31	44	63	47

c) Analysis of simple effects: priming effect per repetition (rep)

repetition	MS	F(1;8)	p
rep 1	242103	11.804	$<.05$
rep 2	470849	22.956	$<.01$
rep 3	962900	46.946	$<.01$

MS_e=20511

Table 8.4 (continued): Results of experiment 14

d) Mean reaction time (ms) per group, repetition (rep), and context and priming effect per group and repetition

	group 1				group 2			
context	rep 1	rep 2	rep 3	mean	rep 1	rep 2	rep 3	mean
primed	659	560	516	579	606	577	567	584
unprimed	666	607	600	624	663	619	610	631
mean	663	584	558	601	635	598	588	607
priming effect	7	47	84	45	57	42	43	47

e) Analysis of simple effects: priming effect per group and repetition (rep)

condition	MS	F(1;8)	p
group 1			
rep 1	5123	.250	ns
rep 2	261965	12.772	<.01
rep 3	795741	38.796	<.01
group 2			
rep 1	389730	19.001	<.01
rep 2	210321	10.254	<.05
rep 3	214197	10.443	<.05

MS_e=20511

8.4 Discussion

In experiments 13 and 14, disyllabic response words, beginning in a stressed CVC-syllable, were primed by their onset consonant, their initial CV-group, or their entire first syllable. Significant priming effects were obtained in all three conditions. The CVC-primes were more efficient than the CV- and the C-primes, whose effects were about equally pronounced. These results are summarized in figure 8.1 together with the findings from experiments 7 and 11, in which CV-response words were tested and same types of primes were used.

As the figure shows, the two types of response words were primed equally efficiently by their initial consonants; the priming effects amounted to 27 ms and 28 ms, respectively. But the remaining two types of primes yielded substantially stronger effects when the response words began in a CV-syllable than when they began in a CVC-syllable.

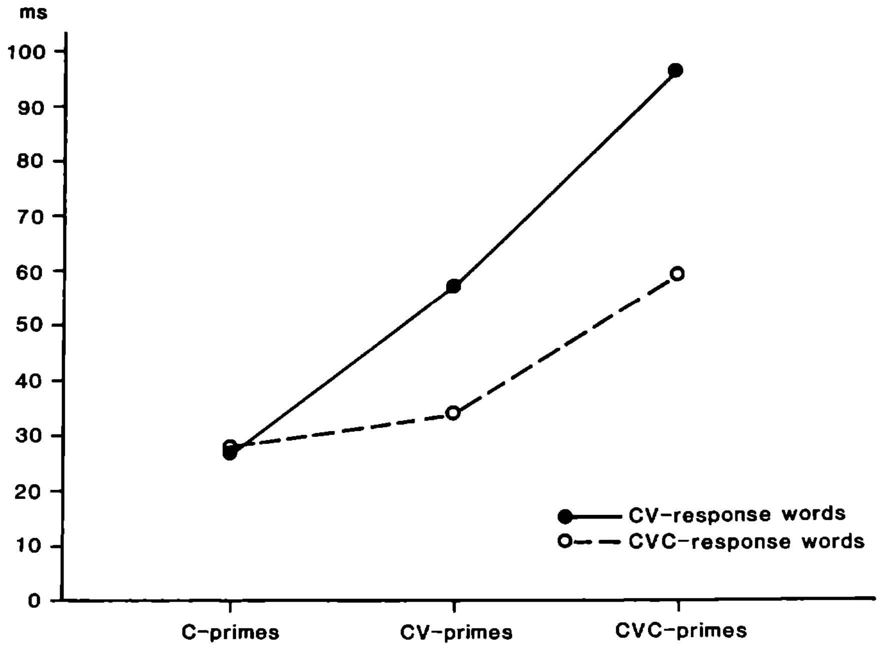


Figure 8.1: Priming effects obtained from C-, CV-, and CVC-primes for CV- and CVC- response words.

Since experiment 11, which tested CV-response words, and experiment 14, in which CVC-response words were used, were based on the same design, their results could be compared in a joint analysis of variance. The interaction of "experiments" and "contexts" was significant ($F(1;16)=5.915$, $MS_e=17584$, $p<.05$), indicating that the priming effect was stronger in experiment 11 than in experiment 14. The difference between the experiments was more pronounced for the CVC- than for the CV-primes (37 ms vs. 23 ms), but the two-way interaction of "experiments", "set types", and "contexts" was not significant ($F(1;16)=2.143$, $MS_e=2917$).[2]

Figure 8.1 also shows that CV- and CVC-response words were primed equally efficiently by their first syllables; priming effects of 57 ms and 59 ms were obtained. The same pattern of results had been found in a pilot study in which CV- and CVC-response words were primed by their initial syllables. The priming effect was significant (means: 570 ms and 600 ms for the homogeneous and the heterogeneous test context; $F(1;8)=6.429$, $MS_e=99129$, $p<.05$) and equally pronounced for both types of response words (means: 29 ms vs. 31 ms).

Taken together, the results show that the effects of the implicit primes were *not* exclusively determined by the number of phonological segments they included, as the "segment hypothesis" predicts. Instead, the effects of the CV- and CVC-primes were modified by the way they mapped onto the syllabic structure of the response words.

This leaves the "position hypothesis" and the "constituent hypothesis". Both correctly predict that the CV- and CVC-group should be more efficient primes for CV- than for CVC-response words and that effects of about the same magnitude should be observed when the two types of response words are primed by their complete initial syllable, irrespective of the number of phonological segments that syllable is composed of.

There are two pieces of evidence arguing against the "position hypothesis". Under that hypothesis, the priming effect should increase by a constant amount with each additional terminal position of the initial syllable included in the prime. A C-prime maps onto one position of a CV-response word, a CV-prime onto three, and a CVC-prime onto four positions. Therefore, the effects of C- and CV-primes should differ more strongly from each other than the effects of CV- and CVC-primes. This was, however, not the case. The difference in the priming effects obtained from C-and CV-primes was *smaller* than the difference between CV- and CVC-primes (28 ms vs. 39 ms). Second, when CVC-response words were used, the strength of the priming effect increased significantly from the CV- to the CVC-primes, as predicted, but, contrary to expectation, the effects of C- and CV-primes did not differ at all.

The "constituent hypothesis", on the other hand, predicts that the effects of C- and CV-primes on the encoding of CV-response words should differ about as much from each other as the effects of CV- and CVC-primes because each time, one additional syllable constituent is primed. The finding that C- and CV-strings were equally efficient primes for CVC-response words was not predicted under that hypothesis either; the CV-primes should have been slightly more efficient than the C-primes (section 8.1). This prediction was based on the assumption that, although the phonological segments of a syllable constituent are normally activated and selected in parallel, it should be possible to select one segment and associate it to its position prior to the other segments of the syllable constituent if it is primed. The results of experiment 13 suggest that this presupposition was incorrect and that the segments of the VC-rhyme must be activated and selected at the same time. Presumably, no priming effect was obtained from the vowel of the VC-rhyme because the vowel could not be selected without the following consonant.

It was suggested above (section 7.8) that the phonological segments of a syllable attain the current node status one after the other and are selected in that order. This is apparently not true for the segments which map onto the positions of a VC-rhyme. One way to modify the current node principle to the effect that the segments of such a rhyme become highly activated at the same time is to assume a higher-level node representing the cluster of segments, which at a certain moment becomes the current node and then activates the two segments in parallel (see Dell, 1986).

This account of the results of experiment 13 raises the question of why the segments of the rhyme must be selected synchronously. Recall that the rhyme of a Dutch word-internal syllable with a full vowel includes two positions, which can either be taken by a long vowel or by a short vowel and a consonant. Which of these options is realized in a given syllable might depend on the temporal order in which the phonological segments reach the selection threshold. If during the encoding cycle for the rhyme only one vowel reaches the selection threshold, it is associated to both rhyme positions, thereby becoming long. A consonant which is selected a little later is linked to the following syllable constituent. If a vowel and a consonant reach the threshold more or less simultaneously, one rhyme position is filled by the vowel, the other by the consonant. The syllable template specifies that the more sonorous segment must be associated to the first position and the less sonorous one to the second position. Thus, a vowel and a consonant can only be associated to the two positions of the rhyme if they are activated and selected at the same time.

Whether complex syllable constituents other than VC-rhymes are encoded in the same way remains to be established. On the one hand, it can be argued that only vowels can be linked to either one or two terminal positions of a syllable. The consonants of an onset cluster can only be associated to one position each; hence, it might be possible to select one consonant of a cluster and associate it to its position independently of the other consonant.

On the other hand, in linguistic theory syllables are often viewed as templates specifying certain constraints on the strings of segments that may be associated to their positions. A given sequence of phonological segments and the terminal positions of a given syllable can only be mapped onto each other, if the segments meet the constraints of the syllable template. One of the main linguistic arguments in support of syllable constituents comprising two or more adjacent terminal positions is based on the existence of collocational constraints, which define possible combinations of segments in these positions (see section 2.3). For example, the Dutch syllable template not only specifies a range of possible sonority values for each onset position, but also a minimum sonority difference which must be exceeded by the segments in the two positions.

It is assumed here that during the phonological encoding of a word, its syllabic structure and its melody are built up independently and are subsequently linked to each other. One might speculate that this association between the units of the two tiers is only possible if the selected segments meet the requirements of the syllable templates of the word, as has been suggested in linguistic theory. One can regard the syllabic structure as a monitor which only admits phonotactically legal strings of segments. The reason why the segments of a syllable constituent must be selected simultaneously might be that some of the phonotactic constraints of the constituent refer to combination of segments in adjacent positions. Whether or not a given segment may be associated to one position of a constituent often depends on certain characteristics of the segment associated to the other position. Hence, the monitor must inspect both segments together in order to decide whether or not they may be linked to the positions of the constituent.

The most important conclusion from the findings reported in this chapter is that the phonological representation of a word generated in language production includes a description of its syllabic structure. On the basis of the experimental results reported in chapter 7, it was argued that the segments of a word are not linearized by reference to the syllable frames. Rather, the units of the syllabic structure and the melody are retrieved and ordered independently of each other. But the time course of the generation of the syllabic structure and the melody is tightly coordinated. In each encoding cycle, the positions of one syllable constituent are filled by the segment or cluster which is maximally activated at that moment.

Notes

1. CVC-response words were primed by the initial CV-group in experiment 13 as well as in experiment 14. This redundancy in the experimental conditions was necessary because the effects of C- vs. CV-primes and of CV- vs. CVC-primes

should be compared within subjects, but only two types of sets could be tested in each experiment.

2. In this analysis, "sets" is not a meaningful design factor. Therefore, the analysis was based on within-subject means per set type, context, repetition, and trial. Significant main effects were obtained for "experiments" ($F(1;16)=12.533$, $MS_e=157191$, $p<.01$) and "contexts" ($F(1;16)=102.190$, $MS_e=17585$, $p<.01$). The interaction of "set types" and "contexts" was also significant ($F(1;16)=42.443$, $MS_e=2917$, $p<.01$), which reflects the fact that in both experiments the CVC-primes were more efficient than the CV-primes.

9 Summary and conclusions

9.1 Summary of the experimental results

In the implicit priming experiments reported above, a paired-associate learning task was used. The experiments consisted of alternating presentation and test phases. In a presentation phase, the subjects studied three or five word pairs which were subsequently tested. In each trial of the following test block, one member of a pair (the prompt) was presented, to which the subject reacted by saying the second member of the pair (the response word) as quickly as possible. The word pairs were tested several times each, in a random order. There were two types of test blocks, homogeneous and heterogeneous ones. The response words of a homogeneous block were phonologically related to each other, sharing, for instance, the first or the second syllable or the onset of the first syllable. The recurrent phonological segment or string of segments is called the implicit prime. In the heterogeneous blocks, the same word pairs were used as in the homogeneous ones, but they were grouped differently, namely in such a way that the response words within a block were not phonologically related to each other in a systematic fashion. The dependent variable was the response latency, defined as the time-interval between the onset of the prompt and the beginning of the articulation of the response word (chapter 5).

The experimental results can be summarized in the following way: first, certain types of implicit primes speeded the responses, others had no effect at all. That is, in certain homogeneous blocks, the mean reaction time was shorter than in the corresponding heterogeneous blocks, while in other homogeneous blocks, the reaction time was the same as in the heterogeneous blocks.

Second, only those implicit primes reduced the response latency which included the beginning of the response words. Disyllabic response words could be efficiently primed by their first syllable, but not by their second syllable and by their word onset consonant, but not by the rhyme of the first syllable. Similarly, a priming effect was obtained from the onset, but not from the rhyme of monosyllabic response words (chapters 6 and 7).

Third, the strength of the priming effect increased with the length of the implicit prime. The word onset of disyllabic response words was a weaker implicit prime than the entire first syllable, which in turn was less efficient than a prime which also included the onset of the next syllable (chapter 7). When trisyllabic words were primed by their first *and* second syllable, a stronger effect was observed than when they were primed by their first syllable alone (chapter 6).

Finally, the strength of the priming effect could be predicted more accurately on the basis of the number of primed syllable constituents than on the basis of the number of primed phonological segments. For instance, an implicit prime consisting of two segments, the word-initial CV-group of disyllabic response words (CV-prime), had a stronger effect when the response words began in a CV-syllable (CV-response words) than when they began in a CVC-syllable (CVC-response words). In the former case, the implicit prime corresponded to two complete syllable constituents, the onset and the rhyme of the first syllable; in the latter case, it mapped onto one complete constituent (the onset) and part of the next constituent (the rhyme). Furthermore, CV-response words were primed as efficiently by their initial *two* segments as CVC-response words by their initial *three* segments. In both cases, the entire first syllable of the response words was primed, and the effect was the same. Finally, a priming effect was obtained from a single segment if it corresponded to a complete syllable constituent, but not if it was part of a complex constituent whose second segment was not primed (chapter 8).

As was argued above (chapter 5), the implicit primes could not facilitate the selection of the response words. The homogeneous and heterogeneous blocks of an experiment included the same number of word pairs. In each trial one out of three or five response words had to be selected. There is no reason why the selection from a group of phonologically related response words should be any easier than the selection from a group of unrelated response words.

In chapters 6 and 7, it was argued that the priming effect could not be exclusively due to articulatory preparation either. This claim is supported by the finding that priming effects were obtained for word-internal syllables and segments, such as the second syllable of the response words or the onset consonant of that syllable, provided that the preceding part of the words was also primed. Since articulatory preparation can hardly span more than one syllable, these priming effects cannot be allocated on the articulatory level, but are likely to stem from facilitation of phonological encoding. On the basis of these results it is reasonable to assume that the effects of word-initial primes were also, at least in part, due to facilitation of phonological encoding.

Presumably, the subjects attempted to use the implicit primes to prepare for the utterance by rehearsing the recurrent strings between the trials and while reading the prompts and selecting the response words. One can think of this rehearsal as the generation and maintenance of a partial phonological representation of the response words, consisting of the string which all response words had in common. The findings that the rehearsal of the first syllable speeded the phonological encoding of the response words and that the rehearsal of the first *and* second syllable led to an even stronger facilitatory effect might not seem particularly surprising since some of the planning of the utterance normally taking place *after* the selection of the response word could already be done before the prompt was read. What is more astonishing is that an implicit prime consisting *only* of the second syllable of the response words could not be used in the same way. The information that the disyllabic response words of a block would, for instance, all end in "-rie" did not speed the reactions at all. Similarly, the subjects could efficiently prepare themselves when the monosyllabic response words shared the word onset, but not when they shared the rhyme. When the subjects knew that the response words of a block would all end in "-aard" and only had to add one phonological segment to the left of this string, the reaction time was not shorter than in the control condition. On the other hand, primes including the onset *and* the rhyme of the first syllable of disyllabic response words were more efficient than primes consisting only of the word onset.

Apparently, it is not possible to prepare for the second syllable of a word without preparing for the first syllable; likewise, it seems to be impossible to prepare for the rhyme of a syllable without preparing for its onset. This suggests that the syllables of a word and the constituents within a syllable can only be encoded in one temporal order, namely according to their sequence in the utterance. I have referred to this conclusion as the "principle of sequential phonological encoding". The phonological representation of a word is created in a series of processing steps, in which successive fragments of the word are encoded, strictly in the order in which they will be uttered. The finding that the strength of the priming effect increased with each additional primed syllable constituent indicates that these fragments are syllable constituents.

9.2 Implications for a model of phonological encoding

The results of the implicit priming experiments have certain implications for a model of phonological encoding, which will now be summarized. As in the derivation of the predictions for the experiments, I will take Dell's (1986) spreading activation model of phonological encoding (see chapter 4) as a frame of reference and will discuss which aspects of the model are supported by the experimental results and which modifications of the theory the findings suggest.

Dell assumes a hierarchy of linguistic units, including morphemes, syllables, phonological segments, and phonological features. In addition, there are cluster nodes representing those segments which map onto a common complex syllable constituent as units. Each segment and cluster node can only be associated to one type of syllable constituent, that is, to an onset, a nucleus, or a coda, and is tagged accordingly.

During the phonological encoding of an utterance, activation spreads in parallel from its morphemes to the sublexical units. At any given moment, one morpheme is selected as the so-called "current node". The morphemes are assigned current node status one after the other, according to their order in the utterance. Upon being selected as the current node, the morpheme node receives an extra boost of activation. It transmits a certain proportion of its activation to its sublexical units, which thereby become more highly activated than the remaining sublexical units. The current node principle also applies to the syllables of polysyllabic morphemes. When such a morpheme is the current node of the morphological representation, one of its syllables is selected as the current syllable. Initially, this is the first syllable of the morpheme, then the second syllable, and so on. The current syllable is activated particularly strongly from the morpheme level and in turn activates its subordinate units more strongly than the remaining syllables.

While the activation is spreading from the morphemes to the sublexical units, the syllable rule is activated again and again, each time creating a frame with the ordered slots onset, nucleus, and coda. At certain time-intervals, the activation levels of the phonological segments and segment clusters are inspected, and each time the most highly activated onset, nucleus, and coda unit that can be found at that moment are selected and inserted into the slots of the frame. When the frame is filled for the first time, the most highly activated segments will normally be those of the first syllable of the utterance because at that moment the first morpheme is the current node on the morpheme level and, if it is polysyllabic, its first syllable is the current node on the syllable level. The three selected units are associated to the syllable constituents in parallel. Then their activation begins to decay. The syllable rule is activated again, and a new current syllable or/and a new current morpheme are selected. When the syllable frame is to be filled for the second time, the segments of the second syllable of the utterance are found to be the most highly activated segments and are inserted into the slots of the syllable frame, and so on. Thus, the phonological encoding of an utterance involves a series of encoding cycles, each devoted to the encoding of one syllable.

The findings of the implicit priming experiments support the idea that the phonological encoding of a morpheme is a serial process proceeding from the beginning of the morpheme to its end and that successive syllables are encoded sequentially. But they do not support the assumption that all segments of a syllable are selected and associated to the syllable constituents in parallel. Instead, they suggest that those segments which map onto successive syllable constituents are selected and associated to their positions sequentially, according to their order in the utterance, whereas those segments which map onto one and the same syllable constituent are selected and linked to the syllable constituent at the same time.

Therefore, I have proposed above to apply the "current node principle", which Dell assumes on the level of the morphemes and syllables, to the level of the segments and clusters (chapter 7). I assume that the sublexical units are selected as soon as their activation reaches a certain threshold and not, as Dell proposes, at fixed time-intervals (chapter 5). The phonological encoding of a morpheme can then be described in the following way: activation spreads from the morpheme node to its segments and clusters. At any given moment, one segment or cluster node is assigned current node status and is activated particularly strongly. Initially, the first segment or cluster is the current node. It reaches the selection threshold first and is associated to the first syllable constituent. Then, the second segment or cluster attains current node status and is selected and associated to the second syllable constituent, and so on, until all segments and clusters of the morpheme are associated to syllable constituents. Thus, the serial order of the segments and clusters is governed by the temporal order of their selection. This holds for the sublexical units within a syllable as well as for those in different syllables.

This description of the time course of phonological encoding sheds a new light on the association between segments and syllable constituents. In Dell's model, the prime function of this process is to order the segments of a syllable, which are taken to be selected simultaneously. But if the segments are linearized by an independent principle, namely the temporal order of their selection, their association to the syllable constituents cannot be viewed as an ordering process any more, and the question arises of why the segments are associated to the slots of the syllable frames at all. This problem was noticed earlier in the discussion of Shattuck-Hufnagel's (1979, 1983) model of phonological encoding, which assumes that the association of segments to syllable constituents is a serial process, but which does not explain why this process takes place (chapter 4).

Above, two functions were attributed to the mapping process. First, in current linguistic theory, phonological representations are viewed as multidimensional objects, which include several independent representational tiers describing different aspects of the word form. One tier is the melody of a word, that is, its description as a string of phonological segments. Another tier of equal importance is its syllabic structure. This representation governs, at least to a large extent, the stress pattern of the word (chapter 2). The association between phonological segments and syllable constituents taking place in phonological encoding can be regarded as an integrative process by which the melody and the syllabic structure are combined to form a complete phonological representation of the word. In this representation, each phonological segment is assigned to a syllable constituent, and each syllable constituent is realized by one or more segments.

Second, a syllable defines certain constraints on the melodies that can be associated to its constituents. One can think of a syllable as a template which includes a set of positions and specifies which class of segments may be linked to each position and which combinations of segments in adjacent positions are permissible. These constraints can, to a large extent, be captured by reference to the sonority values of the segments. For instance, Dutch syllable onsets include one or two positions which must be filled by consonants. If the onset is realized by a cluster, the first consonant must be less sonorous than the second. Word-internal syllable rhymes either comprise one position, which must be taken by a schwa, or two positions, to which either a long vowel or a short vowel and a consonant may be associated. Word-final syllables may include an additional rhyme position, which can only be filled by a consonant (chapter 2).[1] The association between the phonological segments and the terminal positions of the syllabic structure taking place during phonological encoding can be viewed as comparison and validation of the two levels of representations. A minimal criterion for the correct selection of the units of the two tiers is that the string of phonological segments meets the constraints of the syllable templates. If the selected segments cannot be mapped onto the terminal positions of the syllabic structure, an error must have occurred in the generation of at least one of the two representations. A possible reason why those phonological segments which map onto a common complex syllable constituent must be selected simultaneously is that the syllable constituent not only includes constraints referring to each of its individual positions, but also prohibits certain combinations of segments in adjacent positions. Whether a given segment may or may not be associated to a constituent often depends on characteristics of the other segment associated to that constituent.

This altered view of the association between phonological segments and syllable constituents calls for a modification of the notion of the syllable frame. A model which views the mapping of phonological segments and syllable constituents as integration of the melody and the syllabic structure of an utterance must include adequate representations of both tiers. Dell posits only one syllable template with the constituents onset, nucleus, and coda, to which single segments, clusters or "zero-elements" can be associated. This syllable template is sufficient as a frame of reference for the linearization of the phonological segments of a syllable, provided that the segments are tagged with respect to the syllable constituents to which they can be linked. But it does not suffice as a basis for the description of the syllabic structure of an utterance because differences between syllables are not captured at all. Therefore, it seems more adequate to adopt the proposal of nonlinear phonology and to assume a family of syllable templates varying in the number or/and types of constituents they comprise.

The resulting theory is more complex than Dell's model, not only because several syllable templates instead of only one are posited, but also because it must now be specified how the right syllable frame is selected at the right time. Maybe the syllabic structure of an utterance is generated in about the same way as its melody. Each syllable and syllable constituent can be represented as a node in a network. During the phonological encoding of an utterance, activation spreads from the morpheme nodes to the syllables and syllable constituents. At any given moment, one syllable is assigned current node status. If this syllable has more than one constituent, one of them becomes the current node on the constituent level. The current syllable and the current constituent are activated more strongly than the remaining syllables and syllable constituents. The current node status is passed on from syllable to syllable and from constituent to constituent, proceeding from the beginning to the end of the utterance. Initially, the first syllable constituent of the first morpheme is assigned current node status. It reaches the selection threshold before all other constituents and becomes the first constituent in the developing syllabic structure. Then the second constituent of first morpheme or the first constituent of the second morpheme becomes the current node; it reaches the selection threshold next and becomes the second constituent in the syllabic structure, and so on. At the same time, the phonological segments and clusters are activated and selected as described above. While the first syllable constituent is the current node of the syllabic structure, the first phonological segment or cluster is the current node of the melody. These two units reach the selection threshold at about the same time and are associated to each other, provided that the selected segment or cluster meets the constraints of the syllable constituent. Then the second syllable constituent and the second segment or cluster are selected and are subsequently linked to each other, and so on, until the end of the utterance is reached. According to this proposal, the units of the syllabic structure and those of the melody are selected independently of each other, but the time course of their selection is coordinated in such a way that in each encoding cycle, one syllable constituent and one segment or cluster are selected and linked to each other.

A final implication of the findings from the implicit priming experiments concerns the definition of the sublexical units out of which the melody of the utterance is generated. In Dell's model, these are phonological segments and clusters which are marked with respect to the positions in the syllable which they may take. The positional specification of the segments is introduced in order to explain how the segments of a syllable, which are taken to be activated and selected simultaneously, are associated to the correct positions of the syllable frame. The positional specification is not supported by any independent evidence, nor can it be motivated very well on theoretical grounds. There is no such feature as "part of the onset" or "part of the coda" in phonological theory. Furthermore, if each sublexical unit can only be associated to one type of syllable constituent, those segments which can be associated to two constituents must be represented twice with differing positional specifications. Thus, there must be two nodes for each consonant which can take an onset as well as a coda position. Again, this supposition is not based on any empirical evidence.

The experimental results support the assumption that the melody of an utterance is generated by retrieving and combining phonological segments and clusters, but they suggest that the positional specification of these units might be superfluous. If the units of the melody and the syllabic structure are selected sequentially and in tight temporal coordination, as was just proposed, the associations between them are unambiguously determined, and no additional positional specification of the segments is necessary The segment or cluster which is selected first is associated to the first syllable constituent, the segment or cluster which is selected next is associated to the second syllable constituent, and so on until, the end of the utterance is reached.

Only one of the proposed modifications of Dell's theory is directly implied by the results of the implicit priming experiments, namely the assumption that the segments belonging to successive constituents of a syllable are selected sequentially rather than in parallel. The remaining modifications follow quite naturally from this change of the theory, but they are so far not supported by any independent empirical evidence. From a linguistic viewpoint the altered model is probably at least as plausible as Dell's original model. The current research is based on the assumption that the phonological representations generated in language production are structured according to the proposal of nonlinear phonology (chapter 2). Some of the modifications of Dell's theory follow directly from this linguistic framework. This holds, for instance, for the proposition to view the mapping between the melody and the syllabic structure of an utterance as integration of two independent ordered representations rather than as a process necessary to linearize the segments. The assumption that there must be more than one syllable template and that syllables constrain the possible strings of phonological segments that may be associated to their positions is, of course, also adopted from phonological theory.

9.3 Explanation of speech error phenomena

Dell's model of phonological encoding provides a convincing account of important speech error phenomena. The question arises of how the modifications of the model summarized in the last section affect its account for these observations. I will only take up two issues here, which were discussed at length in chapter 3, one concerning the error units in sound errors and the other concerning the constraints on possible locations of misplaced sounds.

The majority of the error units in sound errors can be described as phonological segments or clusters of segments corresponding to syllable constituents of the target word. The error units of slips of the tongue are usually taken to be planning units of language production. In Dell's model, segments are represented as nodes in the network of linguistic units, and the coherence of those segments which map onto one and the same syllable constituent is captured by higher-level nodes representing the clusters. Since the segments and clusters are the units which are selected and combined during phonological encoding, they represent the most frequent type of error unit. Syllables and features become activated, but they are not selected and ordered and are therefore not likely to appear as error units.

This description is, of course, fully compatible with the modifications of Dell's model I have proposed. The results of the implicit priming experiments not only support the assumption that segments and segment clusters are representational units, which are retrieved independently and then combined, but they also show that these units are selected in successive encoding cycles.

A second important observation to be accounted for is the strong tendency of misplaced segments to take positions which are similar to their intended positions. In chapter 3, this tendency was described by reference to two constraints, a word-based and a syllable-based constraint. The former constraint describes the observation that word-initial consonants are far more likely to slip than consonants in other word positions and that they tend to move to word onset positions rather than to word-internal or word-final positions. The latter constraint captures the tendency of segments to move from their target positions to corresponding positions in new syllables, for instance, from a syllable onset to the onset of another syllable rather than to a nucleus or a coda.

To explain the word-based constraint, Dell proposes that the connection of a morpheme node to its initial consonant or consonant cluster might be stronger than the links to the remaining segments; therefore, the onset of an activated morpheme becomes highly activated particularly rapidly. But the amount of activation flowing to the word onset is also more variable than the amount of activation received by other segments. Thus, the onset consonant of the current morpheme becomes very quickly highly activated, but so do the onset consonants of competing morphemes. Because of the increased variability of their levels of activation, reversals of these segments are more likely than reversals of word-internal or word-final segments.

As Dell (1986) notes himself, this explanation of the initialness effect is a plausible suggestion, but it does not follow directly from other assumptions of his theory, nor is it supported by any independent empirical evidence. The validity of this proposal remains to be established. It is, at any rate, consistent with the modified model of phonological encoding suggested here. In fact, in a way the results of the priming experiments support Dell's account of the initialness effect because the segments and clusters of successive syllable constituents were shown to be selected sequentially, beginning with the segment or cluster of the word onset. It seems reasonable that this unit, which is selected first, might become highly activated more rapidly than the units which are selected later.

To account for the syllable-based constraint, Dell refers to the positional specification of the segments. In selecting an insert for a given slot of the syllable frame, only those units are considered which are tagged as suitable for that type of slot. When an onset slot is to be filled, only onset units are considered, and the same holds for the nucleus and coda position, which explains the syllable-based constraint in a straightforward way.

If, as suggested above, the positional specification of the segments is eliminated, a new account of the syllable-based constraint must be found. My proposal is to explain the constraint by reference to the specifications of the syllable templates and by the assumption that only those strings of segments are accepted as part of a phonological representation which can be mapped onto the syllabic structure of the utterance. Consider how the Dutch syllable template constrains the possible locations of misplaced segments. Vowels may only be associated to the first two positions of the rhyme, but not to the positions of the onset or to the last position of the rhyme because these are reserved for less sonorous segments. Conversely, consonants may not be associated to the first position of the rhyme since their sonority value is too low. Thus, by reference to the sonority values which specify the classes of segments that can be associated to each syllable position it can be explained why vowels tend to move into positions meant for other vowels and why consonants move into positions meant for other consonants.

The positions of misplaced segments and clusters are further constrained by the collocational restrictions encoded in the syllable template, that is, by the phonotactic constraints referring to segments in adjacent positions. Most importantly, syllables generally conform to the so-called sonority sequencing generalization, according to which the segments within a syllable are ordered such that their sonority values increase from the margins to the peak of the syllable (Selkirk, 1984). Therefore, most clusters which may appear in prevocalic positions may not appear in postvocalic positions and vice versa.[2] The cluster [kl], for instance, may appear as a syllable onset, but not in the rhyme of a syllable, because [k] is less sonorous than [l]. For the same reason, the cluster [lk] may appear in the rhyme, but not in the onset. This explains why a misplaced onset cluster usually takes a new onset position rather than being associated to a syllable rhyme. More generally, since the syllable templates encode the phonotactic constraints of the language, the requirement that the selected string of segments must be mapped onto the syllabic structure of the utterance rules out all errors that would result in illegal strings.

Furthermore, it also excludes all sound errors which would represent possible melodies of the language, but would not be compatible with the specific syllabic structure of the utterance that is being prepared. For instance, "paraplu" (umbrella) is not likely be uttered as "apraplu", because the new string of segments cannot be mapped onto the syllabic structure of the target word.

Other associations of consonants to new syllable positions are not excluded, however. For example, there is nothing in the syllable template to rule out that "laat" (late) is uttered as "taal" (language) since both consonants can function as onset and as coda of a syllable. According to the most common formulation of the syllable-based constraint (Boomer & Laver, 1968), each segment and cluster is confined to one type of syllable position; therefore, movements of consonants from onset to coda positions and vice versa are excluded. But this formulation might, in fact, be too restrictive. For instance, Shattuck-Hufnagel (1979) reported that this strict constraint was violated in less than 2% of the sound exchanges in her corpus, but in about 30% of the sound anticipations and perseverations. On the other hand, errors resulting in illegal strings of segments are extremely rare (Fromkin, 1971, 1973; Wells, 1951). This is exactly what one expects under the assumption that the constraint is based on the specifications of permissible melodies encoded in the syllable templates.

Notes

1. As was mentioned (chapter 2, note 3), word-initial and word-final syllables may take the affixes. A word-initial cluster can consist of up to three segments and a word-final cluster of up to five consonants.

2. There are certain clusters, which may appear both in prevocalic and postvocalic positions, like, for instance, [st], [sp], and [sk]. Van der Hulst (1984) offers a detailed analysis of these cases. Syllable-initial [s], for example, is analysed as an affix; hence, the syllable onset only includes the following consonant or consonant cluster and does not violate the sonority sequencing generalization.

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Fonologische Codering in Taalproductie

Een Priming Studie

Samenvatting

Theorieën over taalproductie onderscheiden veelal drie typen processen die een rol spelen bij de voorbereiding van een gesproken uiting: het conceptualiseren, dat wil zeggen het vaststellen van de inhoud van de uiting, het formuleren, en de articulatie. Het formuleringsproces kan weer onderverdeeld worden in drie componenten: het selecteren van lexicale elementen, de vorming van de syntactische structuur, en tenslotte het genereren van de fonologische representatie van de uiting. Het laatste proces, ook wel fonologische codering genoemd, is het onderwerp van dit onderzoek. Meer in het bijzonder wordt onderzocht hoe de fonologische representatie van individuele woorden opgebouwd wordt (hoofdstuk 1).

In de linguïstiek wordt de fonologische representatie van een woord vaak beschouwd als een multi-dimensioneel object, bestaande uit onafhankelijke lagen (zogenaamde "tiers"), die verschillende aspecten van de woordvorm bepalen. Eén tier is de melodie; hierin wordt het woora beschreven als een reeks fonologische segmenten. Een andere tier is de syllabische structuur, bestaande uit een reeks lettergrepen. Een lettergreep heeft een hierarchische interne structuur. Hij kan worden onderverdeeld in een onset en een rhyme, welke laatste weer uit een nucleus en een coda bestaat. Ieder van deze lettergreepconstituenten omvat één of meer eindknopen, zogenaamde "slots", waaraan de fonologische segmenten verbonden worden. De eindknopen van de syllabische structuur kunnen beschouwd worden als eenheden van een eigen tier, de skeletal tier, waaraan aan de ene kant fonologische segmenten, aan de andere kant lettergrepen verbonden zijn (hoofdstuk 2).

De psycholinguïstische evidentie ten aanzien van de structuur en de opbouw van fonologische representaties is voornamelijk gebaseerd op de analyse van versprekingen. In ieder corpus van versprekingen wordt een grote hoeveelheid versprekingen aangetroffen waarin de geproduceerde uiting in een fonologisch segment, of in een segmentcluster, verschilt van de bedoelde uiting. Er zijn echter maar zeer weinig versprekingen waar de uiting in een complete syllabe, of in een individueel fonologisch kenmerk van de bedoelde uiting verschilt.

De incorrecte segmenten en clusters die in versprekingen optreden corresponderen meestal met complete lettergreepconstituenten. Bovendien komen segmenten en clusters die te vroeg of te laat geuit worden vaak terecht in een met de oorspronkelijke positie overeenkomende plaats in een andere lettergreep. Ze worden bijvoorbeeld verplaatst van de onset positie van een lettergreep naar de onset van een andere lettergreep, maar niet naar een nucleus of coda positie. Hieruit kan men afleiden dat de fonologische representatie die gevormd wordt tijdens taalproductie niet uitsluitend bestaat uit een reeks fonologische segmenten, maar dat tevens een representatie van de syllabische structuur opgebouwd wordt (hoofdstuk 3).

Een gedetailleerd model van fonologische codering, vooral gebaseerd op evidentie ontleend aan versprekingen, wordt voorgesteld door Dell (1986). Dell veronderstelt een hiërarchie van linguistische eenheden, welke onder meer morfemen, fonologische segmenten, segmentclusters, en fonologische kenmerken omvat. Bij de fonologische codering van een woord worden segmenten en segmentclusters geactiveerd en geselecteerd. Tegelijkertijd wordt een representatie van de syllabische structuur van het woord opgebouwd. Voor iedere lettergreep van het woord wordt daarbij één keer de syllabe-regel geactiveerd. Deze creëert een kader met drie geordende posities die de lettergreepconstituenten onset, nucleus en coda representeren. De gekozen fonemen en clusters worden vervolgens aan deze posities verbonden.

Dell beschouwt de fonologische codering van een taaluiting als een serieel proces, verlopend van het begin naar het eind van de uiting. De volgorde van de linguistische eenheden in de uiting wordt geregeld door twee samenwerkende mechanismen. Zowel de volgorde van de morfemen binnen een uiting, als van de lettergrepen binnen een morfeem, wordt bepaald door de temporele volgorde van hun selectie. De selectie van fonologische segmenten binnen een syllabe daarentegen is een parallel proces. De segmenten worden geordend door de koppeling aan de reeds geordende lettergreepconstituenten (hoofdstuk 4).

Deze veronderstellingen ten aanzien van het tijdsverloop van fonologische codering werden getoetst in drie series experimenten. In de eerste serie werd nagegaan of de opeenvolgende lettergrepen van een woord na elkaar gecodeerd worden (hoofdstuk 6). De tweede en derde serie onderzochten of de sublexicale eenheden binnen een lettergreep parallel geselecteerd en op hun plaats gebracht worden (hoofdstuk 7 en 8).

In deze experimenten werd een nieuw paradigma gebruikt, het zogenaamde impliciete priming paradigma. De experimenten bestonden uit elkaar afwisselende presentatie- en testfasen. In een presentatiefase bestudeerden de proefpersonen een reeks woordparen die in de volgende testfase werden gebruikt. In elk onderdeel van de testfase werd het eerste lid van een woordpaar als "prompt" aangeboden, waarop de proefpersoon zo snel mogelijk moest reageren met het hardop uitspreken van het tweede woord van dit paar (het responswoord). De woordparen werden verschillende keren getest, in een willekeurige volgorde. Er waren twee soorten woordpaarreeksen, homogene en heterogene. De responswoorden binnen een homogene reeks waren fonologisch met elkaar verwant; ze hadden bijvoorbeeld de eerste of de tweede lettergreep of de eerste consonant gemeen. Dit gemeenschappelijke deel wordt de impliciete prime genoemd. De heterogene reeksen bestonden uit dezelfde woordparen als de homogene, maar de woordparen waren zodanig gecombineerd dat de responswoorden binnen een reeks geen systematische fonologische relatie vertoonden. De afhankelijke variabele was de responssnelheid, gedefinieerd als het tijdsinterval tussen het begin van de prompt en het begin van de articulatie van het responswoord (hoofdstuk 5).

De resultaten van de experimenten kunnen als volgt worden samengevat: ten eerste, bepaalde typen van impliciete primes versnelden de respons, terwijl andere typen geen effect hadden. Ten tweede, alleen die primes die het begin van de responswoorden omvatten verkortten de reactietijd (hoofstuk 6). Bovendien nam de grootte van het priming effect toe met de lengte van de impliciete prime. De onset van de eerste syllabe van tweelettergrepige responswoorden was een zwakkere prime dan de complete eerste lettergreep, welke op zijn beurt weer minder efficiënt was dan een prime die tevens de onset van de volgende lettergreep omvatte (hoofdstuk 7).

Tenslotte bleek dat de sterkte van het priming-effect beter voorspeld kon worden op basis van het aantal lettergreepconstituenten waaruit de impliciete prime bestond, dan op basis van het aantal fonologische segmenten. Dezelfde twee woord-initiële segmenten vormden bijvoorbeeld een betere prime wanneer zij overeenkwamen met de volledige eerste lettergreep van de responswoorden dan wanneer zij maar met een gedeelte van deze lettergreep correspondeerden (hoofdstuk 8).

Deze experimentele resultaten suggereren dat de lettergrepen van een woord, en de constituenten binnen een lettergreep alleen in een specifieke temporele orde gecodeerd kunnen worden, namelijk in de volgorde waarin ze in de uiting voorkomen. De fonologische representatie van een woord wordt gespecificeerd in een aantal verwerkingsstappen waarin de opeenvolgende delen van het woord, strikt in de volgorde waarin ze worden geuit, worden gecodeerd. De bevinding dat de sterkte van het priming-effect toeneemt met elke aan de impliciete prime toegevoegde lettergreepconstituent wijst er op dat deze opeenvolgende delen lettergreepconstituenten zijn.

Deze resultaten ondersteunen Dell's aanname dat de fonologische codering van een woord een serieel proces is, verlopend van het begin van een woord naar het eind, en dat opeenvolgende lettergrepen sequentieel worden gecodeerd. De bevindingen bevestigen echter niet de veronderstelling dat alle fonologische segmenten binnen een lettergreep gelijktijdig worden geselecteerd en verbonden met lettergreepconstituenten. De resultaten geven aan dat de segmenten die bij één en dezelfde lettergreepconstituent horen tegelijk worden geselecteerd, terwijl die segmenten die bij opeenvolgende lettergreepconstituenten behoren, sequentieel worden geselecteerd.

Gezien deze uitkomsten werd een modificatie van Dell's model voorgesteld. Volgens dit voorstel wordt de seriële volgorde van segmenten en clusters geregeld door de volgorde waarin ze in de tijd geselecteerd worden. Dit geldt niet alleen voor de verschillende lettergrepen, maar in afwijking van het model van Dell, ook voor de eenheden binnen een lettergreep.

Deze beschrijving van het tijdsverloop van fonologische codering werpt een nieuw licht op de functie van het associatieproces tussen fonologische segmenten en lettergreepconstituenten. In het model van Dell, waar de segmenten van een lettergreep gelijktijdig worden geselecteerd, wordt door dit proces de ordening van de segmenten binnen de lettergreep geregeld. Als de linearisatie van de segmenten echter reeds gebeurt door de volgorde van hun selectie, dan hoeft de associatie met de lettergreepconstituenten niet meer de functie van ordeningsproces te vervullen.

Aan het associatieproces kunnen twee andere functies worden toegeschreven. In de eerste plaats kunnen, in het licht van recente linguistische theorieën de melodie en de syllabische structuur van een woord gezien worden als twee onafhankelijke, geordende representaties die de woordvorm op verschillende manieren coderen. De associatie van fonologische segmenten, de eenheden van de melodie, met lettergreepconstituenten moet beschouwd worden als een integratieproces, waarin de melodie en de syllabische structuur worden gecombineerd tot een complete fonologische representatie.

Ten tweede kunnen de lettergrepen beschouwd worden als sjablonen die restricties definiëren ten aanzien van de melodieën die met hun constituenten kunnen worden geassocieerd. De verbinding tussen fonologische segmenten en lettergreepconstituenten kan gezien worden als een vergelijking en validering van de twee representaties. Een eerste criterium voor de juiste selectie van eenheden van de twee tiers is dat de reeks fonologische segmenten aan de restricties van het lettergreepsjabloon beantwoordt. Als de geselecteerde segmenten niet op de lettergreepconstituenten afgebeeld kunnen worden, moet er een fout zijn opgetreden in de vorming van tenminste een van de twee representaties.

Dit alternatieve beeld van de associatie van fonologische segmenten en lettergreepconstituenten vereist een modificatie van de notie lettergreep. Voor het model van Dell is één lettergreeppatroon met de plaatsen onset, nucleus, en coda voldoende als een referentiekader voor de linearisatie van de segmenten binnen een lettergreep. Het is echter niet voldoende voor de beschrijving van de syllabische structuur van een uiting, omdat geen rekening wordt gehouden met verschillen tussen lettergreepstructuren. Het ligt daarom voor de hand het voorstel uit de recente fonologie aan te nemen en een familie van lettergreeppatronen te veronderstellen, welke variëren in aantal en/of type constituenten dat ze bevatten.

Een dergelijke theorie is complexer dan het model van Dell, niet alleen omdat meerdere lettergreeppatronen worden verondersteld in plaats van een enkele, maar ook omdat nu bepaald moet worden hoe op het juiste moment het juiste lettergreeppatroon geselecteerd wordt. Tot dusverre is weinig bekend over dit proces. In hoofdstuk 9 wordt voorgesteld dat de syllabische structuur van een woord op dezelfde manier gegenereerd wordt als de melodie. Lettergrepen en lettergreepconstituenten kunnen voorgesteld worden als knopen in een netwerk, die geselecteerd worden overeenkomstig hun volgorde in de uiting. Tegelijkertijd worden de eenheden van de melodie geactiveerd en geselecteerd. Op het moment dat de eerste lettergreepconstituent geselecteerd is, is ook het eerste fonologische segment of de eerste cluster gekozen, waarna de eenheden van beide tiers met elkaar verbonden worden. Vervolgens worden de tweede eenheid van de syllabische structuur en de bijbehorende eenheid van de melodie geselecteerd en aan elkaar gekoppeld, enzovoort, tot het eind van het woord. In dit voorstel worden de eenheden van de syllabische structuur en die van de melodie onafhankelijk van elkaar geselecteerd, maar het tijdsverloop van hun selectie is nauwkeurig gecoördineerd, zodat aan het einde van iedere coderingscyclus een lettergreepconstituent en een of meerdere fonologische segmenten zijn geselecteerd en gekoppeld.

Een laatste gevolgtrekking van de uitkomsten van de impliciete priming experimenten betreft de definitie van sublexicale eenheden waaruit de melodie van de uiting wordt opgebouwd. In het model van Dell zijn dit fonologische segmenten en clusters die gemarkeerd zijn met betrekking tot hun positie in de lettergreep. De experimentele resultaten geven ondersteuning aan segmenten en clusters als eenheden, maar suggereren dat de specificatie van hun positie overbodig is. Als de eenheden van de melodie tier en van de syllabische structuur sequentieel en in de tijd precies gecoördineerd gekozen worden, is hun associatie ondubbelzinnig bepaald en is geen aparte specificatie van de positie van fonologische segmenten noodzakelijk.

Appendix A

Stimulus materials of the implicit priming experiments

This appendix summarizes the stimulus materials of experiments 1 to 14. Part a) of each table lists the word pairs of the experimental sets and of the practice set. Part b) shows how the items were combined in the heterogeneous blocks, listing the response words of one heterogeneous block in each column. Part c) provides an English translation of the word pairs.

Table A.1: Stimulus materials of experiment 1

a)

1	/boe/	2	/ka/	3	/le/
straf	boete	touw	kabel	docent	lezing
roof	boeven	poes	kater	pokken	lepra
reis	boeking	woning	kamer	vork	lepel
huisraad	boedel	sjeik	kalief	soldaat	leger
vrouw	boezem	peddel	kano	dood	leven

4	/po/	5	/si/	practice set	
bridge	poker	cola	sinas	heer	dame
doel	poging	fluit	citer	pond	kilo
stoel	poten	graan	silo	sigaar	tabak
stand	pose	vezel	sisal	spijker	hamer
contract	polis	ring	sieraad	hond	poedel

b)

6	7	8	9	10
boete	boeven	boeking	boedel	boezem
kabel	kater	kamer	kalief	kano
lezing	lepra	lepel	leger	leven
poker	poging	poten	pose	polis
sinas	citer	silo	sisal	sieraad

c)

1		2		3	
punishment	fine	rope	cable	lecturer	lecture
robbery	scoundrel	puss	tomcat	smallpox	leprosy
trip	booking	house	room	fork	spoon
effects	property	sheik	caliph	soldier	army
woman	bosom	paddle	kano	death	life

4		5		practice set	
bridge	poker	coke	orange soda	gentleman	lady
goal	attempt	flute	zither	pound	kilo
chair	legs	grain	silo	cigar	tobacco
posture	pose	fibre	sisal	nail	hammer
contract	policy	ring	jewellery	dog	poodle

Table A.2 Stimulus materials of experiment 2

The practice set was retained from experiment 1

a)

1	/ding/	2	/ma/	3	/rie/
nieuws	melding	zaak	firma	zweet	porie
zee	branding	ziekte	reuma	roem	glorie
vertrek	scheiding	luipaard	poema	reeks	serie
eten	voeding	onderwerp	thema	onzin	larie
jurk	kleding	toneel	drama	steppe	prairie

4	/to/	5	/zel/
circus	salto	touw	vezel
besluit	veto	sneeuw	ijzel
camera	foto	steen	kiezel
bedrag	conto	vet	reuzel
wagen	auto	wesp	horzel

b)

6	7	8	9	10
melding	branding	scheiding	voeding	kleding
firma	reuma	poema	thema	drama
porie	glorie	serie	larie	prairie
salto	veto	foto	conto	auto
vezel	ijzel	kiezel	reuzel	horzel

c)

1		2		3	
news	mention	business	firm	sweat	pore
sea	surf	illness	rheumatism	glory	honour
departure	separation	leopard	puma	sequence	series
food	nourishment	subject	theme	nonsense	fiddlestikcs
dress	clothing	stage	drama	steppe	prairie

4		5	
circus	somersault	rope	fibre
decision	veto	snow	glazed frost
camera	photograph	stone	pebble
amount	account	fat	lard
waggon	car	wasp	hornet

Table A.3: Stimulus materials of experiment 3

a)

1	/boe/	2	/de/	3	/ko/
winkel	boetiek	schouwburg	decor	ster	komeet
monnik	boeddhist	magazijn	depot	haas	konijn
kippen	boerin	professor	decaan	soldaat	kozak
tulpen	boeket	kenmerk	detail	rif	koraal
wol	bouclé	misdaad	delict	namaak	kopie

4	/ra/	5	/si/	practice set	
afgrond	ravijn	boom	cipres	krant	rubriek
vliegtuig	raket	aanhaling	citaat	schoen	sandaal
bericht	rapport	fruit	citroen	woestijn	kameel
stamppot	ragout	medicijn	siroop	zaak	bedrijf
komkommer	radijs	rook	sigaar	tand	gebit

b)

6	7	8	9	10
boetiek	boeddhist	boerin	boeket	bouclé
decor	depot	decaan	detail	delict
komeet	konijn	kozak	koraal	kopie
ravijn	raket	rapport	ragout	radijs
cipres	citaat	citroen	siroop	sigaar

c)

1		2		3	
shop	boutique	theatre	décor	star	comet
monk	Buddhist	warehouse	depot	hare	rabbit
chicken(pl.)	woman farmer	professor	dean	soldier	cossack
tulips	bouquet	mark	detail	reef	coral
wool	bouclé	crime	offence	imitation	copy

4		5		practice set	
abyss	ravine	tree	cypress	newspaper	column
aeroplane	rocket	quotation	citation	shoe	sandal
message	report	fruit	lemon	desert	camel
hotchpotch	ragout	medicin	syrup	business	company
cucumber	radish	smoke	cigar	tooth	set of teeth

Table A.4 Stimulus materials of experiment 4

The practice set was retained from experiment 3.

a)

1	/ket/	2	/maat/	3	/niek/
kolen	briket	grootte	formaat	machine	techniek
snack	kroket	chemie	bromaat	angst	paniek
gerecht	parket	sla	tomaat	ziekte	kliniek
bom	raket	weer	klimaat	kleed	tuniek
tulpen	boeket	gorilla	primaat	verhaal	kroniek

4	/ces/	5	/tuur/
voortgang	proces	erfgoed	cultuur
uiterste	exces	riem	ceintuur
verlof	reces	glas	montuur
zwelling	abces	boek	lektuur
triomf	succes	aard	natuur

b)

6	7	8	9	10
briket	kroket	parket	raket	boeket
formaat	bromaat	tomaat	klimaat	primaat
techniek	paniek	kliniek	tuniek	kroniek
proces	exces	reces	abces	succes
cultuur	ceintuur	montuur	lektuur	natuur

c)

1		2		3	
coal	briquet	size	format	machine	technique
snack	croquette	chemistry	bromate	fear	panic
court	public prosecutor	lettuce	tomato	illness	clinic
bomb	rocket	weather	climate	robe	tunic
tulips	bouquet	gorilla	primate	story	chronicle

4		5	
progress	process	inheritance	culture
extreme	excess	strap	belt
leave	recess	glass	frame
swelling	abscess	book	reading
triumph	success	character	nature

Table A.5 Stimulus materials of experiment 5

a)

type 1 sets

1	/ar/	2	/mi/	3	/pe/
bewijs	argument	fruit	mirabel	vogel	pelikaan
voorraad	arsenaal	omroep	microfoon	snoep	pepermunt
olijf	artisjok	gesteente	mineraal	leraar	pedagoog

type 2 sets

4	/inte/	5	/kolo/	6	/para/
brein	intellekt	soldaat	kolonel	hel	paradijs
algebra	integraal	pionier	kolonist	worm	parasiet
aandacht	interesse	kleur	koloriet	regen	paraplu

practice set	
krant	redakteur
boek	manuskript
kerk	basiliek

b)

7	8	9	10	11	12
argument	arsenaal	artisjok	intellekt	integraal	interesse
mirabel	microfoon	mineraal	kolonel	kolonist	koloriet
pelikaan	pepermunt	pedagoog	paradijs	parasiet	paraplu

c)

1		2		3	
proof	argument	fruit	mirabelle	bird	pelican
stock	arsenal	broadcasting	microphone	sweets	peppermint
olive	artichoke	stone	mineral	teacher	educator

4		5		6	
brain	intellect	soldier	colonel	hell	paradise
algebra	integral	pioneer	colonist	worm	parasite
attention	interest	colour	colouring	rain	umbrella

practice set	
newspaper	editor
book	manuscript
church	basilica

Table A.6 Stimulus materials of experiment 6

a)

type 1 sets

1	/ba/	2	/di/	3	/e/
kleinigheid	bagatel	consul	diplomaat	label	etiket
sabel	bajonet	onderwijs	didaktiek	toerist	emigrant
kerk	basiliek	orkest	dirigent	kracht	energie

type 2 sets

4	/epi/	5	/kara/	6	/mono/
nawoord	epiloog	vla	karamel	rots	monoliet
deel	episode	tocht	karavaan	paraaf	monogram
klier	epifyse	geweer	karabijn	toespraak	monoloog

practice set	
boek	manuskript
regen	paraplu
olijf	artisjok

b)

7	8	9	10	11	12
bagatel	bajonet	basiliek	epiloog	episode	epifyse
diplomaat	didaktiek	dirigent	karamel	karavaan	karabijn
etiket	emigrant	energie	monoliet	monogram	monoloog

c)

1		2		3	
trifle	bagatelle	consul	diplomat	label	tag
sabre	bayonette	education	didactics	tourist	emigrant
church	basilica	orchestra	conductor	force	energy

4		5		6	
afterword	epilogue	custard	caramel	rock	monolith
part	episode	journey	caravan	initials	monogram
gland	epiphysis	gun	carbine	address	monologue

practice set	
book	manuscript
rain	umbrella
olive	artichoke

Table A.7. Stimulus materials of experiment 7

a)

1	/b/	2	/k/	3	/l/
stoffer	bezem	pond	kilo	onzin	larie
reis	boeking	insekt	kever	munt	lire
melk	boter	toren	koepel	ziekte	lepra
grondvlak	basis	prins	koning	kreng	loeder
kamp	bivak	rivier	kade	bloem	lotus

4	/p/	5	/s/	practice set	
stand	pose	honing	suiker	heer	dame
kerstmis	pasen	bank	sofa	spijker	hamer
slang	python	degen	sabel	docent	lezing
zout	pekel	cola	sinas	sigaar	tabak
luipaard	poema	reeks	serie	hond	poedel

b)

6	7	8	9	10
bezem	boeking	boter	basis	bivak
kilo	kever	koepel	koning	kade
larie	lire	lepra	loeder	lotus
pose	pasen	python	pekel	poema
suiker	sofa	sabel	sinas	serie

c)

1		2		3	
brush	broom	pound	kilo	nonsense	fiddlesticks
trip	booking	insect	beetle	coin	lira
milk	butter	tower	dome	sickness	leprosy
base	basis	prince	king	beast	bitch
camp	bivouac	river	quay	flower	lotus

4		5		practice set	
posture	pose	honey	sugar	gentleman	lady
Christmas	Easter	bench	sofa	nail	hammer
snake	python	sword	sabre	lecturer	lecture
salt	brine	coke	orange soda	cigar	tobacco
leopard	puma	sequence	series	dog	poodle

Table A.8: Stimulus materials of experiment 8

All word pairs with the exception of "ruzie woede" (row fury) had also been used in experiment 7. The two experiments differed in the combination of the items to experimental sets. In the heterogeneous blocks the same combinations of the items were used as in the preceding experiment. The practice set was carried over from experiment 7.

a)

1	/a/	2	/e/	3	/i/
grondvlak	basis	stoffer	bezem	kamp	bivak
rivier	kade	insekt	kever	pond	kilo
onzin	larie	ziekte	lepra	munt	lire
kerstmis	pasen	zout	pekel	slang	python
degen	sabel	reeks	serie	cola	sinas

4	/o/	5	/oe/
melk	boter	reis	boeking
prins	koning	toren	koepel
bloem	lotus	kreng	loeder
stand	pose	luipaard	poema
bank	sofa	ruzie	woede

Table A.9 Stimulus materials of experiment 9

a)

1	/d/	2	/h/	3	/kl/
ballet	dans	tent	hut	rots	klip
schaal	dop	tovenaar	heks	verf	kleur
karakter	deugd	voet	hiel	schoen	klomp
schilder	doek	stapel	hoop	tapijt	kleed
beest	dier	vuur	haard	winkel	klant

4	/p/	5	/st/	practice set	
uiteinde	pool	orkaan	storm	adelaar	valk
kat	poes	dorp	stad	insekt	mier
ruiter	paard	wesp	steek	hart	bloed
duim	pink	mode	stijl	broek	jurk
inkt	pen	trottoir	stoep	zee	meer

b)

6	7	8	9	10
dans	dop	deugd	doek	dier
hut	heks	hiel	hoop	haard
klip	kleur	klomp	kleed	klant
pool	poes	paard	pink	pen
storm	stad	steek	stijl	stoep

c)

1		2		3	
ballet	dance	tent	hut	rock	cliff
shell	(egg)shell	magician	witch	paint	colour
character	virtue	foot	heel	shoe	clog
painter	canvas	pile	heap	carpet	rug
beast	animal	fire	stove	shop	customer

4		5		practice set	
far end	pole	hurricane	storm	eagle	falcon
cat	puss	village	town	insect	ant
horseman	horse	wasp	sting	heart	blood
thumb	little finger	fashion	style	trousers	dress
ink	pen	pavement	doorstep	sea	lake

Table A.10 Stimulus materials of experiment 10

The practice set was retained from experiment 9

a)

1	/aard/	2	/ens/	3	/ol/
kachel	haard	bril	lens	trui	wol
ruiter	paard	douane	grens	spijs	stol
prent	kaart	maag	pens	gat	hol
herberg	waard	dier	mens	kegel	bol
snor	baard	verlangen	wens	aarde	mol

4	/oek/	5	/uif/
roman	boek	havik	duif
schilder	doek	bot	kluif
vis	snoek	trog	ruif
bocht	hoek	grendel	schuif
heks	vloek	kar	huif

b)

6	7	8	9	10
haard	paard	kaart	waard	baard
lens	grens	pens	mens	wens
wol	stol	hol	bol	mol
boek	doek	snoek	hoek	vloek
duif	kluif	ruif	schuif	huif

c)

1		2		3	
oven	stove	spectacles	lens	sweater	wool
horseman	horse	customs	border	almond paste	stollen
print	card	stomach	paunch	hole	cave
inn	landlord	animal	human	cone	sphere
moustache	beard	desire	wish	earth	mole

4		5	
novel	book	hawk	pigeon
painter	canvas	bone	knuckle
fish	pike	trough	rack
bend	corner	bar	bolt
witch	curse	cart	hood

Table A.11: Stimulus materials of experiment 11

In this experiment, all prompts were presented in capitals, since "Rusland" requires capitalization.

a)

type 1 sets

1	/da/	2	/ha/	3	/ki/
rozijn	dadel	spijker	hamer	pond	kilo
tijdstip	datum	vis	haring	steen	kiezel
val	daling	sneeuw	hagel	fruit	kiwi

type 2 sets

4	/hav/	5	/kol/	6	/pol/
rogge	haver	oven	kolen	spel	polo
schip	haven	punt	colon	contract	polis
valk	havik	sinas	cola	Rusland	Polen

practice set	
vader	moeder
straf	boete
piraat	kaper

b)

7	8	9	10	11	12
dadel	datum	daling	haver	haven	havik
hamer	haring	hagel	kolen	colon	cola
kilo	kiezel	kiwi	polo	polis	Polen

c)

1		2		3	
raisin	date	nail	hammer	pound	kilo
time	date	fish	herring	stone	pebble
fall	descent	snow	hail	fruit	kiwi

4		5		6	
rye	oat	oven	coal	game	polo
ship	harbour	full stop	colon	contract	policy
falcon	hawk	orange soda	coke	Russia	Poland

practice set	
father	mother
punishment	fine
pirate	hijacker

Table A.12 Stimulus materials of experiment 12

a)

type 1 sets

1	/boe/	2	/ko/	3	/to/
winkel	boetiek	rif	koraal	komkommer	tomaat
kippen	boerin	namaak	kopie	podium	toneel
tulpen	boeket	soldaat	kozak	geheel	totaal

type 2 sets

4	/bar/	5	/kom/	6	/tab/
schuur	barak	specerij	komijn	rijtje	tabel
hoed	baret	grap	komiek	verbod	taboe
graaf	baron	ster	komeet	sigaar	tabak

practice set	
krant	rubriek
schoen	sandaal
kaper	piraat

b)

7	8	9	10	11	12
boetiek	boerin	boeket	barak	baret	baron
koraal	kopie	kozak	komijn	komiek	komeet
tomaat	toneel	totaal	tabel	taboe	tabak

c)

1		2		3	
shop	boutique	reef	coral	cucumber	tomato
chicken(pl)	woman farmer	imitation	copy	platform	stage
tulips	bouquet	soldier	cossack	whole	total

4		5		6	
barn	shed	spice	cummin	row	table
hat	cap	joke	comic	ban	taboo
count	baron	star	comet	cigar	tobacco

practice set	
newspaper	column
shoe	sandal
hijacker	pirate

Table A.13 Stimulus materials of experiment 13

a)

type 1 sets

1	/p/	2	/s/	3	/t/
dijk	polder	religie	sekte	snelheid	tempo
nootje	pinda	laan	singel	atleet	turner
tijger	panter	emir	sultan	rogge	tarwe

type 2 sets

4	/de/	5	/ka/	6	/sa/
pan	deksel	universiteit	campus	ketjap	sambal
rivier	delta	pastoor	kansel	straf	sanctie
filosoof	denker	woestijn	cactus	geld	saldo

practice set	
meisje	jongen
winter	lente
zeef	filter

b)

7	8	9	10	11	12
polder	pinda	panter	deksel	delta	denker
sekte	singel	sultan	campus	kansel	cactus
tempo	turner	tarwe	sambal	sanctie	saldo

c)

1		2		3	
dike	polder	religion	sect	speed	tempo
(small) nut	peanut	avenue	boulevard	athlete	gymnast
tiger	panther	emir	sultan	rye	wheat

4		5		6	
pan	lid	university	campus	soy sauce	sambal
river	delta	priest	pulpit	punishment	sanction
philosopher	thinker	desert	cactus	money	balance

practice set	
girl	boy
winter	spring
sieve	filter

Table A.14 Stimulus materials of experiment 14

The type 1 sets are identical to the type 2 sets of experiment 13
The practice set was also retained from the preceding experiment

a)

		type 2 sets			
4	/hal/	5	/ker/	6	/mor/
station	halte	kruid	kervel	avond	morgen
gewicht	halter	feest	kermis	kreng	mormel
dammen	halma	gevangenis	kerker	specie	mortel

b)

10	11	12
halte	halter	halma
kervel	kermis	kerker
morgen	mormel	mortel

c)

4		5		6	
station	stop	herb	chervil	evening	morning
weight	dumb-bell	festival	fair	beast	monster
draughts	halma	prison	dungeon	cement	mortar

Appendix B

Results of the analyses of variance

Table B.1 Results of experiment 1

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	18388	1	18388			
ERROR BETWEEN Ss	3634345	8	454293			
WITHIN SUBJECTS						
A (SETS)	944770	4	236192	23 617	0000	< 01
AE	39829	4	9957			
ERROR(A)	320026	32	10001			
B (CONTEXTS)	1113433	1	1113433	34 938	0006	< 01
BE	30180	1	30180			
ERROR(B)	254951	8	31869			
AB	230304	4	57576	13 645	0000	< 01
ABE	9416	4	2354			
ERROR(AB)	135022	32	4219			
C (REPETITIONS)	514791	2	257396	15 050	0004	< 01
CE	13751	2	6876			
ERROR(C)	273652	16	17103			
AC	21816	8	2727			
ACE	14248	8	1781			
ERROR(AC)	191917	64	2999			
BC	19669	2	9834	1 410	2724	
BCE	135832	2	67916	9 739	0020	< 05
ERROR(BC)	111578	16	6974			
ABC	22394	8	2799			
ABCE	12074	8	1509			
ERROR(ABC)	190634	64	2979			
D (TRIALS)	4044	4	1011			
DE	2881	4	720			
ERROR(D)	123909	32	3872			
AD	67591	16	4224	2 226	0074	
ADE	29336	16	1833			
ERROR(AD)	242971	128	1898			
BD	14143	4	3536	1 349	2727	
BDE	2664	4	666			
ERROR(BD)	83865	32	2621			
ABD	49015	16	3063	2 679	0014	
ABDE	14227	16	889			
ERROR(ABD)	146362	128	1143			
CD	32438	8	4055	3 243	0040	
CDE	12874	8	1609	1 287	2654	
ERROR(CD)	80008	64	1250			
ACD	38340	32	1198			
ACDE	40774	32	1274			
ERROR(ACD)	380413	256	1486			
BCD	8218	8	1027			
BCDE	22248	8	2781	2 153	0428	
ERROR(BCD)	82669	64	1292			
ABCD	47361	32	1480	1 202	2187	
ABCDE	51467	32	1608	1 306	1341	
ERROR(ABCD)	315325	256	1232			
TOTAL	10146160	1499	6769			

Note The entries in the last column indicate the significance levels of the effects using conservative F test (df=1,8)

Table B.2 Results of experiment 2

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	59275	1	59275			
ERROR BETWEEN Ss	1451898	8	181487			
WITHIN SUBJECTS						
A (SETS)	88573	4	22143	5 535	0020	< 05
E	48879	4	12220	3 055	0302	
ERROR(A)	128014	32	4000			
B (CONTEXTS)	3354	1	3354			
BE	51568	1	51568	12 258	0081	< 01
ERROR(B)	33655	8	4207			
AB	15829	4	3957	2 365	0731	
ABE	7346	4	1836	1 097	3751	
ERROR(AB)	53551	32	1673			
C (REPETITIONS)	575714	2	287857	28 219	0000	< 01
CE	1223	2	612			
ERROR(C)	163213	16	10201			
AC	9152	8	1144			
ACE	9943	8	1243			
ERROR(AC)	99570	64	1556			
BC	6156	2	3078	1 111	3543	
BCE	64848	2	32424	11 706	0010	< 01
ERROR(BC)	44316	16	2770			
ABC	11037	8	1380	1 014	4354	
ABCE	25303	8	3163	2 324	0292	
ERROR(ABC)	87100	64	1361			
D (TRIALS)	36275	4	9069	2 693	0478	
DE	8625	4	2156			
ERROR(D)	107772	32	3368			
AD	17693	16	1106			
ADE	20483	16	1280			
ERROR(AD)	190513	128	1488			
BD	14805	4	3701	2 648	0507	
BDE	8770	4	2193	1 568	2057	
ERROR(BD)	44733	32	1398			
ABD	33375	16	2086	1 583	0822	
ABDE	11330	16	708			
ERROR(ABD)	168684	128	1318			
CD	11593	8	1449			
CDE	7760	8	970			
ERROR(CD)	102270	64	1598			
ACD	37352	32	1167			
ACDE	37108	32	1160			
ERROR(ACDE)	358220	256	1399			
BCD	22584	8	2823	1 350	2352	
BCDE	15139	8	1892			
ERROR(BCD)	133826	64	2091			
ABCD	41830	32	1307	1 016	4498	
ABCDE	45471	32	1421	1 104	3277	
ERROR(ABCD)	329545	256	1287			
TOTAL	4845275	1499	3232			

Table B.3 Results of experiment 3

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	65593	1	65593			
ERROR BETWEEN Ss	2931894	8	366487			
WITHIN SUBJECTS						
A (SETS)	225605	4	56401	5 264	0026	
AE	78399	4	19600	1 829	1467	
ERROR(A)	342858	32	10714			
B (CONTEXTS)	691190	1	691190	51 805	0002	< 01
BE	82119	1	82119	6 155	0367	< 05
ERROR(B)	106737	8	13342			
AB	26639	4	6660	1 961	1236	
ABE	18514	4	4629	1 363	2680	
ERROR(AB)	108688	32	3396			
C (REPETITIONS)	465523	2	232761	17 856	0002	< 01
CE	116782	2	58391	4 479	0279	
ERROR(C)	208568	16	13035			
AC	11822	8	1478			
ACE	21295	8	2662	1 018	4320	
ERROR(AC)	67291	64	2614			
BC	870	2	435			
BCE	51361	2	25680	3 606	0499	
ERROR(BC)	113962	16	7123			
ABC	15543	8	1943			
ABCE	20166	8	2521	1 091	3813	
ERROR(ABC)	147919	64	2311			
D (TRIALS)	123461	4	30865	7 410	0004	< 05
DE	3525	4	881			
ERROR(D)	133299	32	4166			
AD	33559	16	2097	1 338	1839	
ADE	37257	16	2329	1 486	1145	
ERROR(AD)	200603	128	1567			
BD	7346	4	1837	1 778	1568	
BDE	19822	4	4955	4 798	0041	
ERROR(BD)	33054	32	1033			
ABD	24075	16	1505	1 368	1677	
ABDE	16446	16	1028			
ERROR(ABD)	140792	128	1100			
CD	14963	8	1870	1 326	2464	
CDE	33046	8	4131	2 929	0077	
ERROR(CD)	90273	64	1411			
ACD	40648	32	1270			
ACDE	40291	32	1259			
ERROR(ACD)	361543	256	1412			
BCD	4991	8	624			
BCDE	8049	8	1006			
ERROR(BCD)	97878	64	1529			
ABCD	29475	32	921			
ABCDE	32655	32	1020			
ERROR(ABCD)	324784	256	1269			
TOTAL	7871173	1499	5251			

Table B.4 Results of experiment 4

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	8771	1	8771			
ERROR BETWEEN Ss	1025562	8	128195			
WITHIN SUBJECTS						
A (SETS)	370312	4	92578	10 370	0001	< 05
AE	99123	4	24781	2 776	0430	
ERROR(A)	285691	32	8928			
B (CONTEXTS)	20590	1	20590	1 651	2336	
BE	214074	1	214074	17 168	0036	< 01
ERROR(B)	99753	8	12469			
AB	9972	4	2493			
ABE	10709	4	2677			
ERROR(AB)	104099	32	3253			
C (REPETITIONS)	1068132	2	534066	68 473	0000	< 01
CE	5742	2	2871			
ERROR(C)	124794	16	7780			
AC	13479	8	1685			
ACE	14815	8	1852			
ERROR(AC)	161673	64	2526			
BC	27507	2	13753	4 272	0319	
BCE	229398	2	114699	35 630	0000	< 01
ERROR(BC)	51507	16	3219			
ABC	11791	8	1474			
ABCE	4148	8	519			
ERROR(ABC)	112506	64	1758			
D (TRIALS)	174653	4	43663	19 409	0000	< 01
DE	6014	4	1503			
ERROR(D)	71990	32	2250			
AD	14453	16	903			
ADE	16080	16	1005	1 073	3873	
ERROR(AD)	119889	128	937			
BD	8695	4	2174	2 230	0871	
BDE	15891	4	3973	4 075	0089	
ERROR(BD)	31194	32	975			
ABD	33794	16	2112	2 450	0031	
ABDE	18844	16	1178	1 366	1685	
ERROR(ABD)	110330	128	862			
CD	33374	8	4172	4 878	0002	
CDE	5225	8	653			
ERROR(CD)	54734	64	855			
ACD	37658	32	1177	1 322	1234	
ACDE	29796	32	931	1 046	4052	
ERROR(ACD)	227823	256	890			
BCD	14427	8	1803	1 843	0848	
BCDE	24740	8	3093	3 160	0047	
ERROR(BCD)	62636	64	979			
ABCD	31465	32	983			
ABCDE	35411	32	1107	1 059	3873	
ERROR(ABCD)	267501	256	1045			
TOTAL	5520765	1499	3683			

Table B.5: Results of experiment 5

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	12623	1	12623			
ERROR BETWEEN Ss	7781931	8	972741			
WITHIN SUBJECTS						
A (SETS)	103491	5	20698	1.190	.3311	
AE	44864	5	8973			
ERROR(A)	695801	40	17395			
B (CONTEXTS)	396999	1	396999	12 283	.0081	< 01
BE	96060	1	96060	2 972	.1207	
ERROR(B)	258573	8	32322			
AB	450767	5	90153	9.943	.0000	<.05
ABE	41793	5	8359			
ERROR(AB)	362668	40	9067			
C (REPETITIONS)	2488245	2	1244123	40.043	.0000	<.01
CE	58849	2	29425			
ERROR(C)	497118	16	31070			
AC	66977	10	6698			
ACE	98878	10	9888	1.265	2637	
ERROR(AC)	625180	80	7815			
BC	35218	2	17609	1 009	.3886	
BCE	122983	2	61491	3.523	0529	
ERROR(BC)	279304	16	17457			
ABC	119649	10	11965	1 586	.1258	
ABCE	114458	10	11446	1 517	.1485	
ERROR(ABC)	603691	80	7546			
D (TRIALS)	179007	7	25572	2 387	0325	
DE	245521	7	35074	3.275	.0057	
ERROR(D)	599842	56	10711			
AD	325815	35	9309	1.676	0127	
ADE	231860	35	6625	1.192	.2194	
ERROR(AD)	1555676	280	5556			
BD	30512	7	4359			
BDE	81492	7	11642	2 347	0352	
ERROR(BD)	277727	56	4959			
ABD	162750	35	4650	1.012	4549	
ABDE	149014	35	4258			
ERROR(ABD)	1286177	280	4593			
CD	128945	14	9210	1.223	2687	
CDE	228697	14	16336	2.168	.0132	
ERROR(CD)	843828	112	7534			
ACD	359307	70	5133			
ACDE	383334	70	5476	1.059	.3568	
ERROR(ACD)	2896699	560	5173			
BCD	117378	14	8384	1 215	.2744	
BCDE	82986	14	5928			
ERROR(BCD)	773178	112	6903			
ABCD	359845	70	5141			
ABCDE	392718	70	5610			
ERROR(ABCD)	3260281	560	5822			
TOTAL	30308708	2879	10528			

Table B.6 Results of experiment 6

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	4550346	1	4550346	18 280	0030	< 01
ERROR BETWEEN Ss	1991448	8	248931			
WITHIN SUBJECTS						
A (SETS)	700430	5	140086	8 694	0001	< 05
AE	83913	5	16783	1 042	4074	
ERROR(A)	644502	40	16113			
B (CONTEXTS)	2160528	1	2160528	30 202	0009	< 01
BE	903442	1	903442	12 629	0076	< 01
ERROR(B)	572288	8	71536			
AB	712500	5	142500	11 809	0000	< 01
ABE	22585	5	4517			
ERROR(AB)	482665	40	12067			
C (REPETITIONS)	1484830	2	742415	12 921	0007	< 01
CE	27488	2	13744			
ERROR(C)	919315	16	57457			
AC	61196	10	6120	1 290	2500	
ACE	36860	10	3686			
ERROR(AC)	379609	80	4745			
BC	26862	2	13431	1 694	2141	
BCE	261564	2	130782	16 497	0003	< 01
ERROR(BC)	126841	16	7928			
ABC	72842	10	7284			
ABCE	40406	10	4041			
ERROR(ABC)	583812	80	7298			
D (TRIALS)	163904	7	23415	4 080	0014	
DE	60841	7	8692	1 514	1809	
ERROR(D)	321422	56	5740			
AD	321162	35	9176	2 231	0003	
ADE	161118	35	4603	1 119	3030	
ERROR(AD)	1151825	280	4114			
BD	89021	7	12717	3 993	0016	
BDE	44597	7	6371	2 000	0707	
ERROR(BD)	178358	56	3185			
ABD	223211	35	6377	1 619	0185	
ABDE	148168	35	4233	1 075	3619	
ERROR(ABD)	1102731	280	3938			
CD	200652	14	14332	4 822	0000	
CDE	53344	14	3810	1 282	2293	
ERROR(CD)	332917	112	2972			
ACD	365567	70	5222	1 248	0944	
ACDE	274083	70	3915			
ERROR(ACD)	2344166	560	4186			
BCD	42780	14	3056			
BCDE	128223	14	9159	2 951	0010	
ERROR(BCD)	347595	112	3104			
ABCD	235577	70	3365			
ABCDE	369650	70	5281	1 258	0860	
ERROR(ABCD)	2349925	560	4196			
TOTAL	27857108	2879	9676			

Table B.7 Results of experiment 7

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	1771479	1	1771479	4 500	0647	
ERROR BETWEEN Ss	3149204	8	393650			
WITHIN SUBJECTS						
A (SETS)	437755	4	109439	10 255	0001	< 05
AE	26697	4	6674			
ERROR(A)	341508	32	10672			
B (CONTEXTS)	285107	1	285107	95 713	0001	< 01
BE	114560	1	114560	38 459	0005	< 01
ERROR(B)	23830	8	2979			
AB	27633	4	6908	2 869	0382	
ABE	1968	4	492			
ERROR(AB)	77040	32	2407			
C (REPETITIONS)	749675	2	374838	83 308	0000	< 01
CE	5011	2	2505			
ERROR(C)	71991	16	4499			
AC	6333	8	792			
ACE	6827	8	853			
ERROR(AC)	145716	64	2277			
BC	1937	2	969			
BCE	57847	2	28923	17 514	0002	< 01
ERROR(BC)	26422	16	1651			
ABC	2111	8	264			
ABCE	17250	8	2156	1 712	1124	
ERROR(ABC)	80618	64	1260			
D (TRIALS)	77514	4	19379	11 241	0000	< 05
DE	13452	4	8863	1 951	1252	
ERROR(D)	55166	32	1724			
AD	17532	16	1096			
ADE	26371	16	1648	1 496	1106	
ERROR(AD)	141009	128	1102			
BD	4079	4	1020	1 189	3343	
BDE	9063	4	2266	2 642	0511	
ERROR(BDE)	27445	32	858			
ABD	27309	16	1707	1 723	0498	
ABDE	18026	16	1127	1 137	3281	
ERROR(ABD)	126809	128	991			
CD	13099	8	1637	1 419	2052	
CDE	8139	8	1017			
ERROR(CD)	73830	64	1154			
ACD	34071	32	1065	1 164	2576	
ACDE	49638	32	1551	1 695	0141	
ERROR(ACD)	234255	256	915			
BCD	14701	8	1837	1 187	3205	
BCDE	12305	8	1538			
ERROR(BCD)	99098	64	1548			
ABCD	25607	32	800			
ABCDE	33382	32	1043	1 036	4205	
ERROR(ABCD)	257877	256	1007			
TOTAL	8828298	1499	5889			

Table B.8: Results of experiment 8

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	4055	1	4055			
ERROR BETWEEN Ss	3179362	8	397420			
WITHIN SUBJECTS						
A (SETS)	90806	4	22702	5.776	.0016	< 05
AE	32358	4	8089	2 058	1089	
ERROR(A)	125781	32	3931			
B (CONTEXTS)	1034	1	1034			
BE	69705	1	69705	15 097	0049	< 01
ERROR(B)	36936	8	4617			
AB	24469	4	6117	3 050	0304	
ABE	11275	4	2819	1.405	.2538	
ERROR(AB)	64188	32	2006			
C (REPETITIONS)	614052	2	307026	67 250	0000	< 01
CE	1301	2	650			
ERROR(C)	73047	16	4565			
AC	14929	8	1866	1.119	3628	
ACE	2425	8	303			
ERROR(AC)	106762	64	1668			
BC	6564	2	3282	1.367	.2827	
BCE	87801	2	43900	18.291	.0002	<.01
ERROR(BC)	38402	16	2400			
ABC	8975	8	1122			
ABCE	11372	8	1422			
ERROR(ABC)	111770	64	1746			
D (TRIALS)	38410	4	9602	7 845	0003	<.05
DE	6478	4	1620	1 323	2819	
ERROR(D)	39168	32	1224			
AD	16141	16	1009	1.010	.4511	
ADE	10174	16	636			
ERROR(AD)	127854	128	999			
BD	1197	4	299			
BDE	3965	4	991	1.211	.3250	
ERROR(BD)	26189	32	818			
ABD	12176	16	761			
ABDE	21387	16	1337	1 372	.1656	
ERROR(ABD)	124709	128	974			
CD	13565	8	1696	2 127	0453	
CDE	11290	8	1411	1.770	0992	
ERROR(CD)	51018	64	797			
ACD	27253	32	852			
ACDE	21578	32	674			
ERROR(ACD)	231648	256	905			
BCD	4913	8	614			
BCDE	10355	8	1294	1.448	1936	
ERROR(BCD)	57194	64	894			
ABCD	29671	32	927	1.130	.2959	
ABCDE	34818	32	1088	1.326	.1213	
ERROR(ABCD)	210104	256	821			
TOTAL	5848622	1499	3902			

Table B.9 Results of experiment 9

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	60092	1	60092			
ERROR BETWEEN Ss	1636725	8	204591			
WITHIN SUBJECTS						
A (SETS)	398070	4	99517	11 205	0000	< 05
AE	45664	4	11416	1 285	2959	
ERROR(A)	284220	32	8882			
B (CONTEXTS)	424061	1	424061	33 470	0007	< 01
BE	39383	1	39383	3 108	1136	
ERROR(B)	101358	8	12670			
AB	112669	4	28167	8 258	0002	< 05
ABE	14560	4	3640	1 067	3894	
ERROR(AB)	109153	32	3411			
C (REPETITIONS)	783521	2	391760	25 444	0001	< 01
CE	8868	2	4434			
ERROR(C)	246347	16	15397			
AC	14079	8	1760			
ACE	8350	8	1044			
ERROR(AC)	176602	64	2759			
BC	7253	2	3627			
BCE	94338	2	47169	12 765	0007	< 01
ERROR(BC)	59124	16	3695			
ABC	13042	8	1630			
ABCE	4923	8	615			
ERROR(ABC)	116235	64	1816			
D (TRIALS)	44361	4	11090	3 864	0114	
DE	14006	4	3501	1 220	3214	
ERROR(D)	91843	32	2870			
AD	16485	16	1030			
ADE	24398	16	1525			
ERROR(AD)	212157	128	1657			
BD	5484	4	1371	1 166	3441	
BDE	18894	4	4723	4 018	0095	
ERROR(BD)	37621	32	1176			
ABD	14062	16	879			
ABDE	18191	16	1137			
ERROR(ABD)	169276	128	1322			
CD	26977	8	3372	1 843	0849	
CDE	11963	8	1495			
ERROR(CD)	117130	64	1830			
ACD	54974	32	1718	1 400	0819	
ACDE	17295	32	540			
ERROR(ACD)	314042	256	1227			
BCD	4378	8	547			
BCDE	7763	8	970			
ERROR(BCD)	74343	64	1162			
ABCD	27068	32	846			
ABCDE	29830	32	932			
ERROR(ABCD)	338244	256	1321			
TOTAL	6449421	1499	4302			

Table B.10 Results of experiment 10

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	35380	1	35380			
ERROR BETWEEN Ss	1674279	8	209285			
WITHIN SUBJECTS						
A (SETS)	354250	4	88563	15.907	0000	< 01
AE	19120	4	4780			
ERROR(A)	178167	32	5568			
B (CONTEXTS)	7840	1	7840	1 731	2234	
BE	55261	1	55261	12 202	0082	< 01
ERROR(B)	36232	8	4529			
AB	19252	4	4813	1.808	1508	
ABE	14310	4	3577	1 344	2746	
ERROR(AB)	85185	32	2662			
C (REPETITIONS)	683300	2	341650	44 955	0000	< 01
CE	4505	2	2253			
ERROR(C)	121598	16	7600			
AC	14221	8	1778	1.124	.3593	
ACE	19314	8	2414	1 527	.1653	
ERROR(AC)	101209	64	1581			
BC	37092	2	18546	13 325	.0006	<.01
BCE	10002	2	5001	3 593	0504	
ERROR(BC)	22269	16	1392			
ABC	7114	8	889			
ABCE	21974	8	2747	2.561	.0172	
ERROR(ABC)	68647	64	1073			
D (TRIALS)	58628	4	14657	6 036	0013	< 05
DE	4074	4	1018			
ERROR(D)	77708	32	2428			
AD	8676	16	542			
ADE	15113	16	945	1 030	.4300	
ERROR(AD)	117354	128	917			
BD	7426	4	1856	1.816	.1494	
BDE	2834	4	709			
ERROR(BD)	32723	32	1023			
ABD	12123	16	758			
ABDE	18352	16	1147	1 163	.3059	
ERROR(ABD)	126221	128	986			
CD	29080	8	3635	3.362	.0031	
CDE	5297	8	662			
ERROR(CD)	69204	64	1081			
ACD	22326	32	698			
ACDE	17649	32	552			
ERROR(ACD)	204403	256	798			
BCD	22140	8	2768	3.993	.0009	
BCDE	9424	8	1178	1 700	.1153	
ERROR(BCD)	44360	64	693			
ABCD	30337	32	948			
ABCDE	19081	32	596			
ERROR(ABCD)	243913	256	953			
TOTAL	4788966	1499	3195			

Table B.11 Results of experiment 11

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	133008	1	133008			
ERROR BETWEEN Ss	4529511	8	566189			
WITHIN SUBJECTS						
A (SETS)	776452	5	155290	13 029	.0000	< 01
AE	35299	5	7060			
ERROR(A)	476759	40	11919			
B (CONTEXTS)	4148338	1	4148338	69 364	.0001	<.01
BE	166484	1	166484	2 784	.1315	
ERROR(B)	478440	8	59805			
AB	410300	5	82060	11.208	.0000	<.05
ABE	51767	5	10353	1 414	.2393	
ERROR(AB)	292853	40	7321			
C (REPETITIONS)	3268607	2	1634304	42 093	.0000	<.01
CE	24691	2	12345			
ERROR(C)	621215	16	38826			
AC	59060	10	5906	1 122	3560	
ACE	20432	10	2043			
ERROR(AC)	420994	80	5262			
BC	116113	2	58056	4 255	.0322	
BCE	114847	2	57423	4.209	.0332	
ERROR(BC)	218305	16	13644			
ABC	60952	10	6095	1 720	.0902	
ABCE	36319	10	3632	1.025	.4310	
ERROR(ABC)	283557	80	3544			
D (TRIALS)	333048	7	47578	8.630	.0000	< 05
DE	39532	7	5647	1 024	.4251	
ERROR(D)	308723	56	5513			
AD	199956	35	5713	1 628	.0174	
ADE	108486	35	3100			
ERROR(AD)	982340	280	3508			
BD	87419	7	12488	2 802	0142	
BDE	21442	7	3063			
ERROR(BD)	249613	56	4457			
ABD	290916	35	8312	2 305	.0002	
ABDE	104805	35	2994			
ERROR(ABD)	1009508	280	3605			
CD	101887	14	7278	2 285	0088	
CDE	42998	14	3071			
ERROR(CD)	356737	112	3185			
ACD	183503	70	2621			
ACDE	191481	70	2735			
ERROR(ACD)	1981292	560	3538			
BCD	29941	14	2139			
BCDE	66932	14	4781	1 532	.1109	
ERROR(BCD)	349578	112	3121			
ABCD	260703	70	3724	1 187	.1533	
ABCDE	169888	70	2427			
ERROR(ABCD)	1757074	560	3138			
TOTAL	25972105	2879	9021			

Table B.12 Results of experiment 12

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	729825	1	729825	2 493	1509	
ERROR BETWEEN Ss	2342385	8	292798			
WITHIN SUBJECTS						
A (SETS)	236192	5	47238	3 067	0193	
AE	81520	5	16304	1 058	3981	
ERROR(A)	616157	40	15404			
B (CONTEXTS)	2368193	1	2368193	55 896	0002	< 01
BE	33474	1	33474			
ERROR(B)	338943	8	42368			
AB	219752	5	43950	8 297	0001	< 05
ABE	37264	5	7453	1 407	2419	
ERROR(AB)	211880	40	5297			
C (REPETITIONS)	2424094	2	1212047	202 225	0000	< 01
CE	29907	2	14953	2 495	1127	
ERROR(C)	95897	16	5994			
AC	61050	10	6105			
ACE	54145	10	5415			
ERROR(AC)	542953	80	6787			
BC	10125	2	5063			
BCE	195048	2	97524	5 736	0131	< 05
ERROR(BC)	272044	16	17003			
ABC	21963	10	2196			
ABCE	19128	10	1913			
ERROR(ABC)	663622	80	8295			
D (TRIALS)	146759	7	20966	3 902	0019	
DE	28284	7	4041			
ERROR(D)	300866	56	5373			
AD	111851	35	3196			
ADE	115393	35	3297			
ERROR(AD)	1111254	280	3969			
BD	26565	7	3795	1 129	3581	
BDE	62770	7	8967	2 668	0185	
ERROR(BD)	188208	56	3361			
ABD	172949	35	4941	1 296	1310	
ABDE	78139	35	2233			
ERROR(ABD)	1067282	280	3812			
CD	60106	14	4293	1 092	3727	
CDE	77391	14	5528	1 406	1619	
ERROR(CD)	440463	112	3933			
ACD	288178	70	4117	1 233	1068	
ACDE	218891	70	3127			
ERROR(ACD)	1870064	560	3339			
BCD	45321	14	3237	1 147	3257	
BCDE	96983	14	6927	2 455	0049	
ERROR(BCD)	316078	112	2822			
ABCD	178798	70	2554			
ABCDE	252798	70	3611	1 006		
ERROR(ABCD)	2011184	560	3591			
TOTAL	20872137	2879	7250			

Table B.13 Results of experiment 13

SOURCE	MS	df	SS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	617	1	617			
ERROR BETWEEN Ss	7637439	8	954680			
WITHIN SUBJECTS						
A (SETS)	663295	5	132659	10 006	0000	< 05
AE	81480	5	16296	1 229	3131	
ERROR(A)	530339	40	13258			
B (CONTEXTS)	467279	1	467279	20 021	0024	< 01
BE	139557	1	139557	5 979	0388	< 05
ERROR(B)	186718	8	23340			
AB	118213	5	23643	3 284	0140	
ABE	38054	5	7611	1 057	3988	
ERROR(AB)	287992	40	7200			
C (REPETITIONS)	1541019	2	770509	35 632	0000	< 01
CE	57101	2	28550	1 320	2945	
ERROR(C)	345987	16	21624			
AC	86355	10	8635	1 260	2665	
ACE	25194	10	2519			
ERROR(AC)	548127	80	6852			
BC	7241	2	3621			
BCE	146224	2	73112	5 484	0151	< 05
ERROR(BC)	213313	16	13332			
ABC	28257	10	2826			
ABCE	67657	10	6766	1 104	3694	
ERROR(ABC)	490274	80	6128			
D (TRIALS)	136555	7	19508	3 219	0063	
DE	59938	7	8563	1 413	2178	
ERROR(D)	339331	56	6059			
AD	175554	35	5016	1 013	4540	
ADE	110951	35	3170			
ERROR(AD)	1386580	280	4952			
BD	13986	7	1998			
BDE	34800	7	4971	1 290	2716	
ERROR(BD)	215855	56	3855			
ABD	140283	35	4008			
ABDE	208771	35	5965	1 456	0529	
ERROR(ABD)	1147461	280	4098			
CD	88038	14	6288	1 410	1598	
CDE	100034	14	7145	1 602	0890	
ERROR(CD)	499474	112	4460			
ACD	379497	70	5421	1 349	0375	
ACDE	288646	70	4124	1 026	4255	
ERROR(ACD)	2251341	560	4020			
BCD	42493	14	3035			
BCDE	107256	14	7661	1 903	0330	
ERROR(BCD)	451022	112	4027			
ABCD	253852	70	3626			
ABCDE	222967	70	3185			
ERROR(ABCD)	2217320	560	3960			
TOTAL	24579738	2879	8538			

Table B.14 Results of experiment 14

SOURCE	SS	df	MS	F	p	p(con)
BETWEEN SUBJECTS						
E (GROUPS)	23049	1	23049			
ERROR BETWEEN Ss	3015692	8	376962			
WITHIN SUBJECTS						
A (SETS)	629026	5	125805	7 550	0001	< 05
AE	19237	5	3847			
ERROR(A)	666520	40	16663			
B (CONTEXTS)	1554482	1	1554482	34 013	0006	< 01
BE	233	1	233			
ERROR(B)	365622	8	45703			
AB	232032	5	46406	5 165	0012	
ABE	33191	5	6638			
ERROR(AB)	359400	40	8985			
C (REPETITIONS)	2974536	2	1487268	56 838	0000	< 01
CE	436096	2	218048	8 333	0036	< 05
ERROR(C)	418670	16	26167			
AC	62223	10	6222	1 235	2818	
ACE	63227	10	6323	1 254	2700	
ERROR(AC)	403232	80	5040			
BC	121369	2	60685	7 667	0049	< 05
BCE	260688	2	130344	16 467	0003	< 01
ERROR(BC)	126647	16	7915			
ABC	49071	10	4907			
ABCE	56533	10	5653			
ERROR(ABC)	479950	80	5999			
D (TRIALS)	46601	7	6657	1 114	3673	
DE	12585	7	1798			
ERROR(D)	334642	56	5976			
AD	178345	35	5096	1 440	0581	
ADE	138697	35	3963	1 120	3021	
ERROR(AD)	990882	280	3539			
BD	35141	7	5020	1 266	2830	
BDE	46866	7	6695	1 689	1301	
ERROR(BD)	221989	56	3964			
ABD	232428	35	6641	1 729	0088	
ABDE	163500	35	4672	1 216	1961	
ERROR(ABD)	1075498	280	3841			
CD	104506	14	7465	1 737	0575	
CDE	47407	14	3386			
ERROR(CD)	481340	112	4298			
ACD	271377	70	3877	1 050	3746	
ACDE	226051	70	3229			
ERROR(ACD)	2067897	560	3693			
BCD	44869	14	3205			
BCDE	91793	14	6557	1 886	0348	
ERROR(BCD)	389335	12	3476			
ABCD	261976	70	3743	1 232	1073	
ABCDE	276315	70	3947	1 300	0596	
ERROR(ABCD)	1700806	560	3037			
TOTAL	21791570	2879	7569			

Appendix C

Distribution of missing values

Table C.1 displays the frequencies (f) of missing, wrong, disfluent, and slow responses and of technical errors in the homogeneous and heterogeneous test context and in each of the three repetitions, as well as the total frequencies of the five types of errors summarized over all experiments. The table also shows which the percentages (%) of the total of the 111840 data points these frequencies correspond to. Tables C.2 through C.15 display the distributions of the five types of missing values over the groups, sets, contexts, and repetitions of each experiment.

7.66% of all data points were missing. The percentage of missing values per experiment varied from 5.44% to 12.53%. The most frequent type of missing values were disfluencies, with 52.96% of all invalid data falling into this category. The frequencies of missing values decreased over the repetitions; 45.50% of them stemmed from the first repetition, 29.32% from the second repetition, and 25.18% from the third repetition.

Missing and slow responses were slightly more frequent in the heterogeneous than in the homogeneous condition, whereas the reverse held for wrong and disfluent responses. For each experiment, the frequencies of missing, wrong, disfluent, and slow responses in the homogeneous and heterogeneous test context were compared by means of Wilcoxon-tests. The resulting z-scores are included in the below tables, with significant values being marked by "*" ($p<.05$) or "**" ($p<.01$). In most cases, the context effect was not significant.

Table C.1· Distribution of missing values over the test contexts and repetitions, summarized over all experiments

	types of missing values											
condition	missing responses		wrong responses		disfluent responses		slow responses		technical errors		total	
	f	%	f	%	f	%	f	%	f	%	f	%
context												
primed	385	34	501	45	2576	2 30	635	57	503	45	4600	4 11
unprimed	423	38	310	28	2044	1 83	723	65	470	.42	3970	3 55
repetition												
1	470	42	275	25	2006	1 79	771	69	377	34	3899	3 49
2	197	18	284	25	1403	1 25	323	29	306	27	2513	2 25
3	141	13	252	23	1211	1 08	264	24	290	26	2158	1 93
total	808	72	811	73	4620	4 13	1358	1 21	973	87	8570	7 66

Table C.2 Distribution of missing values in experiment 1

condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
		types of missing values				
group						
1	12	20	149	55	84	320
2	35	25	134	40	85	319
set						
1 /boe/	27	30	75	40	35	207
2 /ka/	5	3	46	12	26	92
3 /le/	3	3	48	9	45	108
4 /po/	9	7	70	15	33	134
5 /si/	3	2	44	19	30	98
context						
primed	29	37	149	32	91	338
unprimed	18	8	134	63	78	301
z=	1.180	2 666**	917	2.650**		
repetition						
1	25	9	129	44	55	262
2	12	18	93	24	63	210
3	10	18	61	27	51	167
total	47	45	283	95	169	639
%	63	60	3 78	1 27	2 25	8 52

Table C.3· Distribution of missing values in experiment 2

condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
		types of missing values				
group						
1	10	6	295	33	100	444
2	41	33	283	49	90	496
set						
1 /ding/	13	6	87	14	36	156
2 /ma/	7	6	118	25	36	192
3 /rie/	8	3	118	11	31	171
4 /to/	5	10	126	14	40	195
5 /zel/	18	14	129	18	47	226
context						
primed	28	22	300	45	100	495
unprimed	23	17	278	37	90	445
z=	.507	405	770	1.126		
repetition						
1	24	13	222	46	89	394
2	16	9	185	19	57	286
3	11	17	171	17	44	260
total	51	39	578	82	190	940
%	68	52	7 71	1 09	2 53	12 53

Table C.4 Distribution of missing values in experiment 3

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	31	27	102	59	32	251
2	33	16	109	75	13	246
set						
1 /boe/	8	5	53	24	9	99
2 /de/	16	15	40	38	8	117
3 /ko/	10	9	27	17	11	74
4 /ra/	19	4	39	34	9	105
5 /si/	11	10	52	21	8	102
context						
primed	34	32	132	51	25	274
unprimed	30	11	79	83	20	223
z=	.296	2 014*	2.381*	1 955		
repetition						
1	29	16	103	70	20	238
2	18	18	59	29	9	133
3	17	9	49	35	16	126
total	64	43	211	134	45	497
%	85	57	2 81	1.79	60	6.63

Table C.5 Distribution of missing values in experiment 4

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	30	16	92	64	37	239
2	51	13	115	71	22	272
set						
1 /ket/	7	4	42	27	14	94
2 /maat/	9	2	36	28	10	85
3 /niek/	19	8	29	45	13	114
4 /ces/	35	10	54	27	8	134
5 /tuur/	11	5	46	8	14	84
context						
primed	48	18	112	92	31	301
unprimed	33	11	95	43	28	210
z=	1.126	1.095	1.330	2.141*		
repetition						
1	45	14	97	74	20	250
2	21	9	62	44	16	152
3	15	6	48	17	23	109
total	81	29	207	135	59	511
%	1.08	39	2.76	1 80	79	6.81

Table C.6 Distribution of missing values in experiment 5

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	49	35	239	52	15	390
2	53	98	194	103	24	472
set						
1 /ar/	15	23	66	36	8	148
2 /mi/	18	22	101	18	4	163
3 /pe/	5	6	76	22	9	118
4 /inte/	38	42	66	29	7	182
5 /kolo/	16	32	64	27	7	146
6 /para/	10	8	60	23	4	105
context						
primed	53	89	263	56	25	486
unprimed	49	44	170	99	14	376
z=	355	2 030*	2 803**	1 172		
repetition						
1	66	45	183	82	17	393
2	20	44	131	37	7	239
3	16	44	119	36	15	230
total	102	133	433	155	39	862
%	1 18	1 54	5 01	1 79	45	9 98

Table C.7 Distribution of missing values in experiment 6

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	45	48	153	54	9	309
2	25	44	183	31	13	296
set						
1 /ba/	17	15	60	18	5	115
2 /di/	7	15	50	19	6	97
3 /e/	8	10	51	12	4	85
4 /epi/	15	15	42	7	4	83
5 /kara/	9	12	73	13	2	109
6 /mono/	14	25	60	16	1	116
context						
primed	38	50	206	45	8	347
unprimed	32	42	130	40	14	258
z=	490	829	2 395*	070		
repetition						
1	52	22	151	53	11	289
2	13	38	92	20	6	169
3	5	32	93	12	5	147
total	70	92	336	85	22	605
%	81	1 07	3 89	98	26	7 00

Table C.8 Distribution of missing values in experiment 7

condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
	types of missing values					
group						
1	7	14	57	64	25	167
2	16	17	154	33	21	241
set						
1 /b/	9	14	42	29	14	108
2 /k/	3	5	43	18	4	73
3 /l/	5	4	51	14	10	84
4 /p/	3	7	38	28	8	84
5 /s/	3	1	37	8	10	59
context						
primed	14	21	133	54	21	243
unprimed	9	10	78	43	25	165
z=	338	1 050	2 548*	1 050		
repetition						
1	12	14	92	50	18	186
2	6	8	68	27	19	128
3	5	9	51	20	9	94
total	23	31	211	97	46	408
%	31	41	2 81	1 29	61	5 44

Table C.9 Distribution of missing values in experiment 8

condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
	types of missing values					
group						
1	11	18	103	62	22	216
2	15	11	139	41	32	238
set						
1 /a/	1	6	49	12	9	77
2 /e/	6	12	62	27	9	116
3 /i/	14	6	57	25	10	112
4 /o/	4	3	34	23	15	79
5 /oe/	1	2	40	16	11	70
context						
primed	13	17	118	55	25	228
unprimed	13	12	124	48	29	226
z=	021	1 099	510	652		
repetition						
1	16	12	105	51	15	199
2	3	8	68	27	16	122
3	7	9	69	25	23	133
total	26	29	242	103	54	454
%	35	39	3 32	1 38	72	6 05

Table C.10 Distribution of missing values in experiment 9

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	24	28	83	49	26	210
2	46	38	105	51	20	260
set						
1 /d/	16	15	38	21	9	99
2 /h/	19	12	42	22	14	109
3 /kl/	20	29	56	30	9	144
4 /p/	7	4	19	18	7	55
5 /st/	8	6	33	9	7	63
context						
primed	26	31	96	47	26	226
unprimed	44	35	92	53	20	244
z=	1 775	490	140	.930		
repetition						
1	43	21	75	66	16	221
2	15	25	63	16	13	132
3	12	20	50	18	17	117
total	70	66	188	100	46	470
%	93	88	2 51	1 33	61	6 27

Table C.11 Distribution of missing values in experiment 10

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	10	45	87	34	28	204
2	15	12	146	31	49	253
set						
1 /aard/	3	18	45	10	15	91
2 /ens/	4	4	25	11	17	61
3 /ol/	2	13	53	16	17	101
4 /oek/	3	9	41	14	17	84
5 /uif/	13	13	69	14	11	120
context						
primed	14	41	138	39	40	272
unprimed	11	16	95	26	37	185
z=	.105	2.073*	1 540	1 121		
repetition						
1	16	17	98	46	37	214
2	7	25	78	13	24	147
3	2	15	57	6	16	96
total	25	57	233	65	77	457
%	33	76	3 11	87	1 03	6 09

Table C.12 Distribution of missing values in experiment 11

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	15	37	230	8	26	316
2	15	19	214	10	24	282
set						
1 /da/	4	8	82	5	8	107
2 /ha/	6	16	107	2	11	142
3 /ki/	3	13	84	2	6	108
4 /hav/	5	3	52	5	13	78
5 /kol/	6	7	60	2	7	82
6 /pol/	6	9	59	2	5	81
context						
primed	4	36	205	5	27	277
unprimed	26	20	239	13	23	321
z=	2 521*	1 718	415	1 363		
repetition						
1	19	16	185	10	18	248
2	9	17	128	6	21	181
3	2	23	131	2	11	169
total	30	56	444	18	50	598
%	35	65	5 14	21	58	6 92

Table C.13 Distribution of missing values in experiment 12

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	33	39	256	45	30	403
2	40	36	160	38	18	292
set						
1 /boe/	15	14	101	7	14	151
2 /ko/	13	6	73	17	5	114
3 /to/	2	8	45	11	5	71
4 /bar/	21	12	71	11	12	127
5 /kom/	14	29	77	17	6	143
6 /tab/	8	6	49	20	6	89
contexts						
primed	25	49	234	31	26	365
unprimed	48	26	182	52	22	330
z=	1 820	1 988*	1 896	1 185		
repetition						
1	45	31	187	56	13	332
2	19	26	121	17	20	203
3	9	18	108	10	15	160
total	73	75	416	83	48	695
%	85	87	4 81	9 61	56	8 04

Table C.14 Distribution of missing values in experiment 13

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	28	26	193	50	48	345
2	17	29	209	52	44	351
set						
1 /p/	11	11	43	29	13	107
2 /s/	6	6	68	17	12	109
3 /t/	5	14	55	15	15	104
4 /de/	1	4	73	8	17	103
5 /ka/	13	16	81	24	17	151
6 /sa/	9	4	82	9	18	122
context						
primed	22	25	214	40	43	342
unprimed	23	30	188	62	49	354
z=	.592	.0	1 274	1 153		
repetition						
1	27	23	179	53	34	316
2	15	20	130	23	21	209
3	3	12	93	26	37	171
total	45	55	402	102	92	696
%	52	64	4 65	1 18	1 07	8 06

Table C.15 Distribution of missing values in experiment 14

	types of missing values					
condition	missing responses	wrong responses	disfluent responses	slow responses	technical errors	total
group						
1	60	35	276	64	12	447
2	41	26	160	40	24	291
set						
1 /de/	9	5	65	13	8	100
2 /ka/	27	8	80	28	6	149
3 /sa/	23	10	111	19	6	169
4 /hal/	17	18	67	15	5	122
5 /ker/	9	4	58	8	8	87
6 /mor/	16	16	55	21	3	111
context						
primed	37	33	276	43	15	404
unprimed	64	28	160	61	21	334
z=	2 028*	.663	2 488*	1 352		
repetition						
1	51	22	200	70	14	357
2	23	19	125	21	14	202
3	27	20	111	13	8	179
total	101	61	436	104	36	738
%	1 17	71	5 05	1 20	41	8 54

Curriculum Vitae

Antje S. Meyer werd geboren op 15 december 1957 te Hemer, West-Duitsland. Aldaar bezocht zij het Friedrich-Leopold-Woeste Gymnasium en deed in 1976 het eindexamen. Vervolgens studeerde zij Psychologie, Filosofie, Engels en Sociale Wetenschappen aan de Ruhr-Universität in Bochum waar zij in 1983 de graad van Diplom-Psychologin behaalde. Na afsluiting van haar studie was zij gedurende een jaar als wetenschappelijk assistente aan het Psychologische Institut der Ruhr-Universität verbonden. Met een stipendium van de Max-Planck-Gesellschaft zur Förderung der Wissenschaften verrichtte zij van 1984 tot 1987 het onderzoek van deze dissertatie aan het Max-Planck-Institut für Psycholinguistik te Nijmegen. Vanaf mei 1987 is zij werkzaam als wetenschappelijk medewerkster aan hetzelfde instituut.

Stellingen

1. The reason why a speaker can prepare for the first phonological segment of a word without knowing the following segments, but cannot prepare for second or third segment without knowing the preceding ones is that the temporal order in which the segments are selected determines their serial order in the phonological representation and ultimately in the utterance.

   (this thesis)

2. Although the phonological representation of the beginning of a word is created before the representation of the end, the articulation can only begin after the *complete* phonological representation has been generated.

3. The syllabic structure of an utterance functions as a monitor admitting only phonotactically legal strings.

   (this thesis)

4. It is not possible to prepare for the stress pattern of a word without knowing its phonological segments.

5. The so-called positional constraint on sound errors, that is, the tendency of misplaced phonological segments to take positions that are similar to their target positions, can largely be explained by reference to the phonotactic constraints encoded in the syllabic structure of the utterance.

   (this thesis)

6. Lay interpreters and professionals differ in the temporal coordination of their speech output with the speech input. In order to minimize memory load, laymen follow the source text very closely, often at the expense of the well-formedness of their utterances. Professional interpreters generally use larger input segments and adjust their size to the constraints imposed by the syntactic structure of the two languages in question.

   (see Bosshardt, H.-G., & Meyer, A. (1985). Simultaneous interpretation: Units and time coordination (Experimentelle Untersuchung des Simultandolmetschens: Einheitenbildung und zeitliche Koordination). *Archiv für Psychologie, 137*, 137-159.)

7. For the intrinsic reference system to apply, *all three* dimensions of the reference object must be in a canonical position with respect to the perceptual frame of orientation of the located object, and not, as Levelt's (1984) Principle of Canonical Orientation implies, only the dimension that is linguistically referred to.

   (see Levelt, W.J.M. (1984). Some perceptual limitations on talking about space. In A.J. van Doorn, W.A. van de Grind, & J.J. Koenderink (Eds.), *Limits in perception: Essays in honour of Maarten A. Bouman* (pp. 323-358). Utrecht: VNU Science Press.)

8. If little time is available for the completion of a psycholinguistic experiment, one should only work with female subjects.

Antje Meyer — Nijmegen, 14.7.1988